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ROCK HISTORY

A NOTE BOOK OF GEOLOGY

C. L. BARNES.

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ROCK HISTORY

ROCK HISTORY

A CONCISE NOTE-BOOK OF GEOLOGY

HAVING SPECIAL REFERENCE TO

The English and Welsh Formations

BY

C. L. BARNES, M.A.
LATE SCHOLAR OF BALLIOL COLLEGE, OXFORD;
SCIENCE MASTER AT LLANDOVERY SCHOOL

WITH MAPS OF STRATA AND ILLUSTRATIONS OF FOSSILS

LONDON
EDWARD STANFORD, 55, CHARING CROSS, S.W.
1884

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PREFACE.

THIS little book has been compiled principally from Lyell's *Student's Elements of Geology,* with occasional aid from other sources, which are for the most part referred to in the footnotes. The main feature in which it differs from other books on the subject consists in the use of tables, wherein the various formations are arranged in their stratigraphical order, and their chief characteristics mentioned not only on the same page, but in the same horizontal line, so that at a glance one can read the name of a formation, its development in England and Wales (and, in certain cases, in foreign countries), its mineral character, chief fossils, and prominent features. In connection with each table is a map of England and Wales, in which only the strata under consideration are depicted, and a plate of fossils is added to illustrate the organisms belonging to each separate period.

A difficulty has been felt in the selection of the most suitable fossils, as is nearly always the case; but at all events the error of overcrowding the plates has been avoided.

A short classification of the Animal and Vegetable Kingdoms is presented on pp. 86-90, which, it is hoped, will fulfil its object, viz. to give the reader just so much information about them as the nature of the book requires.

A fairly copious glossary will be found at the end of the book, in which the meanings and derivations of most of the geological terms in common use are given together with other remarks where it has been thought necessary.

The proofs have been revised by Prof. Etheridge, F.R.S., and I take this opportunity of expressing my sincere thanks to him for the trouble he has taken in so doing.

C. L. B.

LLANDOVERY, *March* 1884.

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ROCK HISTORY.

CHAPTER I.

GENERAL PRINCIPLES.

THE Earth on which we live is a globe, vast, ancient, wonderful, instinct with life and motion, and worthy of study from any point of view, whether we consider it as an atom among the countless stars by which it is surrounded, or as an immense habitation for animal and vegetable life.

The sciences of Physics, Chemistry, Biology, and Physiography concern themselves with phenomena which are presented naturally, or are artificially brought about on its surface; Astronomy, with a boundless realm of its own, deals with the relations to each other of the masses of matter scattered through space; while Geology, deriving aid from all these branches, considers the form and structure of the earth, the changes that have taken place during its past history, and looks on the present state of things as the outcome of all that has gone before,—nor is it content with retrospection, but prophesies what changes, within its own province, will take place in the future.

Of late years immense progress has been made in all

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departments of Natural Science, and the greatest perhaps in Geology, as is fitting, seeing that it is the most comprehensive of them all. In some parts of the Middle Ages it was thought beneath the dignity of a gentleman to know how to read and write, and though at the beginning of the present century this was not the case, still the old spirit was not altogether extinct in regard to scientific matters, as the following passage from a well-known and classical book will show:—"There is a great deal of trifling in authors and commentators upon the very unimportant question, whether the leading bee of the hive be male or female, king or queen. As I feel very little interest in the subject, or rather none at all, I cannot dispose myself to examine it. Time must be of little value to those who can write a volume on such a subject. It is amazing, indeed, how nearly the follies of the learned and the sports of children approach each other in unmeaning and frivolity."[1]

Now, however, we are happily free from such prejudices, and the march of Science progresses with the consent and good wishes of all except a few of the most narrow-minded.

To return to our subject. All researches, whether physical or astronomical, into the past history of the earth tend to show that many millions of years ago it was in a molten condition, revolving on its axis more rapidly than at present, and the scene of violent chemical and seismic disturbances. The water was probably all in the form of steam, but as the crust began to form and to thicken, it was condensed and may have covered the whole surface till the great oceanic areas were marked out.[1] Then the earliest forms of life appeared, either as a special act of creation or as a step in the sequence of events, and henceforward the same changes went on that we see in progress now,—land was elevated and depressed; earthquakes shook the crust and volcanoes poured out lava over it; rivers deepened their channels and brought down sediment to their mouths; new and higher forms of life came into existence, while others became extinct; the seasons held their course, spring, summer, autumn, and winter succeeding to each other, each with its accompaniment of rain or snow and ice, and so on.

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[1] *Travels of Anacharsis*, notes to chap. v. (1817).

As to the thickness of the crust on which all this took place, opinions are still unsettled. From observations on the temperatures in mines, artesian wells, and borings at different depths, it appears that, after the first hundred feet, each additional 50 or 60 feet is accompanied with a rise of 1° Fahr.; so that at a depth of 50 miles the temperature would be over 5000°, sufficient to melt the most infusible substances. In this calculation, however, two assumptions are made, one of which is demonstrably untrue, viz. that the increase of pressure produces no increase of melting-point; the other is improbable, viz. that the increase is perfectly regular down to the greatest depths. That there is a large quantity of liquid matter in the interior of the earth is shown by the emission of lava from volcanoes; but whether they are supplied by a universal ocean underneath a few miles of crust, or from local reservoirs of comparatively small extent, does not appear. At this point physical and astronomical calculations are brought in to show that unless the earth as a whole has a rigidity equal to that of a ball of glass, or even of steel the same size, it must yield to the tide-producing influences of the sun and moon in such a way as to make the actual oceanic tides less than they really are, and this, it is maintained, could not be the case were the crust less than 800 or 1000 miles thick. Against the hypothesis of a rigid globe, Dana, as a geologist, urges that by it the source and extent of volcanic and other igneous actions are insufficiently accounted for, as also the occurrence of faults and contortions; and on the other hand, that the explanation of subsidences and upheavals over wide areas, as in the Pacific Ocean and the Appalachian region, presents no difficulty on the assumption of a thin crust over a liquid interior.[1]

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[1] This probably occurred at a very early period. See Wallace, *Island Life*, pp. 97-102.

The time that has elapsed since the crust began to form is estimated at about 100,000,000 years, and all geological history is comprised within that interval. To consider in detail the formation of rocks; which of them were formed by water, which by fire or other agencies; their order of deposition, thickness, structure, and other peculiarities; the effect on them of rain, ice, rivers or the sea, and of earthquakes, volcanoes, and other igneous agencies; the varieties of animal and vegetable life which they supported at different times, and the traces which these latter have left behind,—is the object of our Science.

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[1] For a further consideration of this question, see Dana's *Manual of Geology*, pp. 808-815 (1880).

CHAPTER II.

OF ROCKS.

By the word Rock, as used in the preceding chapter, is meant any solid material forming a part of the earth's crust, whether such material be hard like marble or granite, soft like clay or soil, loose like sand or gravel, or soluble in water like rock-salt. Rocks are classified in the first instance according to their origin: those which have been formed by water alone are termed aqueous rocks; by fire alone, igneous; by water and subsequently fire, metamorphic; and by the accumulation of animal or vegetable remains, organic.

A group of rocks having some feature in common, whether of age, origin, or composition, is called a "formation"; thus we speak of cretaceous, sedimentary, or arenaceous formation, meaning thereby a group of rocks of cretaceous age, sedimentary origin, or sandy composition respectively. The word is of course used in its ordinary sense of "act or manner of forming" as well.

The great majority of rocks have been deposited from water in much the same way that mud gathers at the bottom of a pond, viz. by the effect of gravity on solid particles held in suspension. Their ultimate source in most cases is to be found in hills or mountains, down whose sides rivulets trickle and join together to form small streams; these, by their union, finally form the tributaries of a river which flows to the sea or to a lake, there to deposit the sediment which has been accumulating during the whole process.

Or again, the sea beating on a shore grinds up the large stones into smaller ones, and these again into fine sand, which oscillates backwards and forwards with each successive tide, to be laid bare eventually as a marine deposit. Bones of quadrupeds, birds, and reptiles; bones, scales, and teeth of fishes; shells of mussels, oysters, crabs, etc.; bodies or wings of insects; leaves and twigs of plants, etc., are some of the remains most usually embedded in greater or less numbers in such deposits, and these or their traces, when afterwards discovered, are termed *fossils.*

Hence we may infer that when fossils are found in a rock, that rock must have been once under water, no matter at what height it is above the sea-level, or how far from any lake or ocean. In the Himalayas, fossils have been found at a height of 18,400 feet, and though their elevation to this altitude is unusual, it is only to be explained on the supposition that the land has been raised, and not the sea lowered. For in the latter case the waters must once have stood at that height all over the earth, and the enormous body of water which this would require, exceeding many thousand times that of all the present lakes and oceans, cannot possibly have been removed elsewhere. On the other hand, we know that land is continually being raised and lowered at the present day; not enough to produce much effect in an ordinary lifetime, but, continued through even a fraction of a geological period, ts of prodigious magnitude might be produced.

The most usual constituents of aqueous rocks are clay, sand, and carbonate of lime; the two former derived from pre-existing rocks by a process of erosion or grinding, the latter usually from the shells and skeletons of low marine organisms.

They have, as a rule, been deposited at no great distance from the shore, for even the fine particles brought down by a river are not usually carried out beyond 50 or 100 miles except under special circumstances. To account for the great thickness of some of the formations (occasionally as much as 30,000 ft.), it is no longer necessary to suppose that the foundations of them were laid in an ocean six miles deep, but that the shore gradually subsided while the depth of water was maintained nearly uniform.

In thus ascribing so much to the elevation and subsidence of land we are not assuming anything which observation at the present day does not warrant,[1] either as to the occurrence of changes of level themselves, or to their amount, while the circumstantial and internal evidence in this particular case is very strong. Professor Geikie remarks, "Among the thickest masses of sedimentary rock, those of the ancient Palæozoic systems, no features occur more continually than the alternations of different sediments, and the recurrence of surfaces covered with well-preserved ripple-marks, trails and burrows of annelids, polygonal and irregular dessication marks like the cracks at the bottom of a sun-dried muddy pool. These phenomena unequivocally point to shallow and even littoral waters. They occur from bottom to top of formations which reach a thickness of several thousand feet. They can be interpreted in only one way, viz. that the formations in question began to be laid down in shallow water; that during their formation the area of deposit gradually subsided for thousands of feet; yet that the rate of accumulation of sediment kept pace on the whole with this depression; and hence that the original shallow-water character of the deposits remained, even after the original sea-bottom had been buried under a vast mass of sedimentary matter."[1] From their manner of formation they tend to lie in more or less horizontal beds, layers, or strata, and a mass in which such a structure is observable is said to be stratified. In digging or boring through an aqueous deposit the character of the mass is usually observed to be different at different levels, being at one time clayey, at another calcareous, at another arenaceous, and so on. Sometimes these alternations occur with great regularity through a considerable thickness, as in the Jurassic series (see table, p. 63); probably owing to changes of level or the deflection of rivers, whereby the deposition of mud over some area ceased for a time and the waters became clear and fit for the growth of zoophytes, whose calcareous remains accumulated during the interval, and were subsequently covered by sand after the old levels were re-established.

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[1] "Daily it is forced home on the mind of the geologist that nothing, not even the wind that blows, is so unstable as the level of the crust of this earth with relation to the sea."—Darwin, *Naturalist's Voyage*, p. 321.

In pursuing a bed horizontally, it is generally found to thin out altogether or to suffer some gradual change in mineral composition without loss of continuity; this is usually owing to a change in the nature of the country from which the sediment is derived; for instance, along the shores of a continent a river may bring down clay from its basin, while on either side of its mouth sand is accumulating from the grinding up of stones on the beach. These deposits would gradually merge into one another and account for the fact alluded to.

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[1] Quoted from *Island Life*, pp. 84-85.

The horizontality of a sedimentary deposit is liable to be interfered with by a number of causes, such as the presence of an elevation or depression in the floor on which it rests, and, in particular, to subsequent upheavals from below, or to lateral pressures caused by some subterranean disturbance. Hence it is rare to find strata perfectly horizontal; as a rule, they incline towards some point or other of the compass, and this fact is expressed by saying that they *dip*, and the amount of inclination they possess is called the "angle of dip."

The end or edge of a stratum which comes out to the surface of the ground is called its *outcrop*, and the direction of the outcrop the *strike*. A good idea of the meaning of these last expressions may be obtained by imagining a venetian blind laid on a table; the separate laths correspond to the different strata, their inclination to the angle of dip, their upper edges to the outcrop, and the direction of these edges to the strike. Again it is easily seen that the length of a lath is measured at right angles to its breadth,—in other words, the strike is at right angles to the dip.

It sometimes happens that the outcrops of a series of strata, after being partly denuded or worn away, have been covered by a new series deposited on them; when this is the case, the two are said to be *unconformable* or to lie unconformably.

If one stratum lying conformably on another extends in any direction beyond the limits of the latter, the arrangement is called an *overlap*. When a bed or set of beds has been bent into curves, these, if small, are called *contortions;* if of greater extent, *anticlines* and *synclines*. The word anticline is from the Greek (*anti*, opposite, and *klino*, to bend), and denotes a curve with its convexity directed upwards like the initial letter A of the word itself; while a synclinal curve (*sūn*, together, and *klino*, to bend) is the precise opposite of this.

A *uniclinal* curve is a single fold of either description without an answering fold of the opposite kind; an example of this occurs in the Isle of Wight, where the beds at the southern part of the island are horizontal, then they dip at a considerable angle towards the north, and recover their horizontality at the northern part. As a rule the anticlines form hills, and the synclines valleys, but amongst the Carboniferous rocks of Lancashire an example is known where this is not the case.[1]

The continuity of a bed or set of beds is frequently interrupted by dislocations termed *faults* (produced also by subterranean forces), where, instead of being folded into curves, they have been broken across; so that, in pursuing such a series in the direction of the layers, we suddenly come upon a place where one part has been thrown up or down out of its proper level. There may or may not be a fissure between the two parts; if so, the grinding together of them may have produced polished or striated surfaces called *slickensides*, or it may simply have filled up the fissure with fragments.

The chief faults in England are the 90-fathom dyke in the Newcastle coal-field, where the difference of level between what would otherwise be continuous parts of the same bed is 540 feet; the Tynedale and Craven faults, also in Northumberland; the fault at Ashby de la Zouch in Leicestershire, 500 feet; the Bala fault in Merionethshire, 10,000 feet, and many in the Lancashire coal-field.

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[1] Lyell, *Student's Elements*, p. 63. Other instances occur in various districts, *e.g.* the United States.

In these cases the dislocations have probably been effected at different stages, and not suddenly or by one movement; and it will be observed that they are all amongst the older rocks; as a general rule these have been more disturbed and altered than more recent ones, for the simple reason that disturbances and alterations are not confined to any one period, but have taken place continually, and in all parts of the earth. The amount of dislocation measured in a vertical direction is termed the *throw* of the fault, and is an upthrow or downthrow according to the side from which it is viewed. The separation usually extends to an indefinite distance downwards, though sometimes with lateral branches of smaller extent; its direction (which may be compared to the dip of a stratum) is termed its *hade* or *underlie.*

CHAPTER III.

CHEMICAL AND OTHER ROCKS.

HITHERTO, in our consideration of aqueous rocks, we have confined ourselves to those of *mechanical* origin,—that is to say, those which have been deposited from suspension in water; but there is another class whose formation is analogous to that of the crust on the bottom of a kettle or steam boiler, where the solids have been in solution until the water evaporated or was made incapable of retaining them by the loss of one of its dissolved gases, viz. carbonic acid.

These deposits are called *chemical*, and the majority of them are composed of carbonate of lime, which, although insoluble in pure water, is soluble to a considerable extent in water containing carbonic acid gas dissolved in it; so that if this gas, whether from the breath or any other source, be passed through dilute lime-water, a cloudiness due to carbonate of lime is first formed, but disappears if the current of gas be continued. On heating the water or allowing it to evaporate at the ordinary temperature, the solid material is left behind. Water in this state is said to be temporarily hard, because the hardness can be removed by boiling, or by adding fresh lime-water. The petrifying springs of Derbyshire and other places owe their qualities to carbonate of lime dissolved in this way, and the stalactites and stalagmites so frequent in caves, especially in limestone districts, have a similar origin.

Travertin, a compact and massive form of carbonate of lime, found, amongst other places, at the bottoms of some of the Italian lakes, on the shores of the river Anio in that country, and of Gardiner's River in the Yellowstone district of North America, is due to the cooling or evaporation of calcareous springs which occur in those localities. The name is a corruption of Tiburtino, from the river Tibur, and the stone was employed for the building of St. Peter's Church at Rome.

Gypsum and alabaster are found in greater or less abundance in many parts of the world, and are composed of sulphate of lime, which, although sparingly soluble in cold water, is more so in hot water under pressure. Water containing this substance in solution is said to be permanently hard, because it cannot be rendered soft by boiling or the addition of lime-water.

The form of silica called *sinter*, which is found round the orifices of geysers in Iceland, the Yellowstone Park, etc., owes its origin to the evaporation of the siliceous waters of the geysers.

Rock-salt is a chemical rock of the highest value, found in almost all parts of the world, but chiefly in Cheshire, at Wieliczka in Galicia, at Cardoña in Catalonia, in Canada and the State of New York, and is usually attributed to the evaporation of saline waters or of inland lakes communicating at intervals with the ocean. It is often associated, for some reason or other, with gypsum in unfossiliferous sandstones coloured red by oxide of iron.

One characteristic feature of chemical rocks is that they do not necessarily tend to form horizontal beds like mechanical deposits, but may encrust the vertical walls of a cliff or fissure.

Rocks made up chiefly or entirely of the remains of animal or vegetable organisms are called ORGANIC. Many limestones, chalk, coral, flint, chert, coal, and peat have been thus formed: the first three are accumulations of the shells or skeletons of animals low in the scale of life, mostly marine, as shell-fish, foraminifera, or coral insects. These creatures have the power of abstracting carbonate of lime from sea-water by some chemico-vital process, in spite of the carbonic acid present, and on their death the hard parts remain; occasionally, as in the case of the chalk, forming deposits of vast extent and thickness. The flints of the Upper White Chalk are also of organic origin, being composed of the remains of siliceous sponges, and of microscopic plants called Diatomaceæ; and though the weight of silica in a single sponge or plant of this kind is very small, it is quite possible that many generations of them grew and died on the same spot, and that the mass of silica afterwards separated itself from the surrounding chalk by a process known as "concretionary action." Chert is distinguished from flint by being tough instead of brittle, and having a splintery instead of a conchoidal fracture. Coal and graphite, on the other hand, are of vegetable origin, and are due to changes in the woody fibre of plants whereby nearly all the water is given off along with some gaseous compounds till the residue is chiefly carbon with a small quantity of earthy matter, the ash. Peat is formed in a peculiar way by the decay of the roots of a variety of plants termed peat-mosses; their upper parts continuing to grow meanwhile till a thickness of sometimes 40 feet is attained.

To come now to IGNEOUS rocks: these are they which have once been in a molten state, and have subsequently cooled down, either with comparative rapidity at or near the surface, or with extreme slowness under enormous pressure. The first sort are called VOLCANIC (and this term also includes the accumulated masses of fragments thrown out from a volcano and afterwards consolidated), the second sort PLUTONIC (from Pluto, the god of the lower regions). From their manner of formation it will easily be seen that there may be every gradation between the two, or indeed that they may form parts of the same mass, blending by insensible passages into one another. Except the fragmental volcanic rocks, both are necessarily devoid of fossils, and the terms unconformability, stratification, and the like, are unknown in connection with them; but in their place we have a number of new terms, such as intrusion, crystallisation, dykes, etc., to describe their position, structure, or appearances.

Igneous rocks are said to be intrusive when they have been forced through sedimentary strata (in which case the character of the latter has usually been altered for a greater or less distance by the heat); if the melted rock has forced its way upwards to the surface, and built up a pile of lava, stones, dust, and ashes round the orifice, the structure is called a volcano. Until lately a volcano was supposed to be the indispensable accompaniment of eruptions from underground; but in Britain, Russia, and the Yellowstone district there are tracts of country where the appearances of the volcanic rocks cannot be explained on this supposition, but are rather the result of the welling up of lava through linear fissures, flooding the country just as water would do.[1] These fissures, when filled in this way, are termed *dykes*, and on the removal of the overlying rocks by denudation would present the appearance of walls running across a country in more or less parallel directions.

Numbers of them are found in Great Britain, their general direction being east and west or north-west and south-east. The majority are on the western side; the longest, however, is on the eastern, running from below Bishop Auckland to Robin Hood Bay, above Scarborough, a distance of 40 miles. Several others in the same vicinity are of considerable, though not equal length.

A mass of lava, in cooling, frequently assumes a columnar structure, the result of contraction; the most notable examples of this kind are Fingal's Cave in the Isle of Staffa, the Giant's Causeway in Ireland, and a somewhat similar erection at Illawarra in New South Wales. The columns in these cases are hexagonal prisms,—that is to say, they have six equal rectangular faces, arranged in three parallel and opposite pairs. Occasionally the columns, on further contraction, split up into globular or polyhedral forms, as in the cheese-grotto of Bertrich-Baden, between Trèves and Coblentz.[2]

Other varieties of structure are exhibited by *porphyries* and *amygdaloids;* the former being composed of a "base" in which are scattered distinct crystals of some mineral, the latter of a cellular mass of which the cavities have been filled up so as to present the appearance of almonds in a pudding.

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[1] See Geikie, *Geological Sketches*, 1882.

[2] Lyell, *Student's Elements*, p. 512.

Stones, cinders, and fine dust are sometimes ejected from volcanoes in such quantity as to form beds of considerable thickness, and these may afterwards become consolidated by their own weight, or by mixture with water. Should circumstances be favourable, they may enclose animal or vegetable remains in the same way as an aqueous deposit.

A mixture of small volcanic stones and dust more or less consolidated is called *tuff:* if the stones are larger, it passes either into a *breccia* or a *conglomerate;* the former if they are rough and angular, the latter if smooth and rounded. Some breccias and conglomerates are of aqueous origin, so that an examination of the component parts is necessary before the character of a particular sample can be decided upon.

To come now to plutonic rocks: they, like the preceding, are of igneous origin, but differ, as already explained, in their manner of cooling. They are further distinguished by the absence of tuffs, breccias, and conglomerates, and of pores and cellular cavities. The difference between the two, however, is one of texture rather than composition; plutonic rocks being in general more crystalline, because the particles have had more time to arrange themselves; and more compact, because the pressure has driven out all the entangled gases. A further difference is that they are always intrusive, and never interbedded,—in other words, they have never been observed to lie between two strata, but always to rise through at some considerable angle with the planes of bedding.

The only remaining class of rocks to be considered is the METAMORPHIC. These are aqueous rocks which have by some means or other been sunk some distance in the earth's crust, and there subjected to the action of an agency termed metamorphism, which probably combines the effects of heat, pressure, and chemical action.

Allusion has already been made to the changes produced in an aqueous deposit by an intrusive volcanic rock; limestone, for instance, may be turned into marble; sandstone into quartzite, a harder and more compact variety; clay to a flinty shale; coal into cinders, and so on, in each case accompanied with partial or total obliteration of the fossils.

Pressure, either alone or with the addition of heat, often produces cleavage, by which is understood a tendency to split into thin plates, such as is exhibited by slate. It can be induced in a homogeneous mass, as shown by the experiments of Professor Tyndall on clay, wax, and other substances, and its direction is at right angles to the pressure. When the mass is not homogeneous, but contains two or more different minerals, they sometimes arrange themselves under the metamorphic influence in more or less distinct layers, giving it almost the appearance of stratification. This structure is called *foliation*, and is well exhibited by gneiss, which contains the same minerals as granite, viz. quartz, felspar, and mica; but instead of being uniformly distributed through the mass, they are collected together in layers, which are most conspicuous in the case of the mica, on account of its darker colour and the flatness of the separate pieces. Other examples of foliated rocks are the various schists, *e.g.* mica-schist, talc-schist, hornblende-schist, etc.; in all of these the cleavage is usually, though it is believed not necessarily, in the direction of the folia.

In connection with the purely chemical effects of metamorphism may be mentioned (1) the replacement of an organic structure by a mineral,—for instance, woody fibre by silica, as in wood opal, or shells of ammonites and other molluscs by iron pyrites; (2) the introduction of some new compound into a pre-existing mineral,—carbonate of magnesia, for example, into common limestone to form magnesian limestone or dolomite; (3) the partial or entire alteration of one mineral into another, distinct in crystalline form or chemical composition, as, for instance, augite into serpentine; mixtures of silicates containing iron, magnesia, potash, etc., into mica or steatite, and so on. Several such changes have been produced artificially by sealing up water containing various substances in solution, in glass tubes exposed to a high temperature for several weeks, or by the percolation of mineral waters through masonry for many centuries; this has actually been the case in the Roman conduits at Plombières in the Vosges, where crystals of aragonite, calcite, fluor-spar, etc., are found in the interspaces of the bricks and mortar.[1]

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[1] See Lyell, *Student's Elements*, p. 585; Jukes, *Manual of Geology*, pp. 364-365.

CHAPTER IV.

THE AGES OF ROCKS.

It is not possible to determine the ages of rocks absolutely, *i.e.* to say exactly how many years have elapsed since a particular stratum began to be formed, or how many were occupied in the process;[1] but it is possible in very many cases to say which is the older of any two rocks, and hence to draw up, with some degree of accuracy, a chronological table of them all. The means at our disposal in this matter vary somewhat with the nature and origin of the rock, and as they are most reliable in the case of aqueous rocks, these will be most suitable as a starting-point.

Of a series of strata arranged one on top of another, it is obvious that the uppermost is the newest, and the lowest the most ancient; also that any particular one is more recent than the bed on which it rests, and older than the one above it, unless they have all been tilted into a vertical position, or turned upside down, in which case it will be advisable to examine them, if possible, in some other region where they have not been subjected to disturbance.

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[1] Some idea of the interval in years may be gathered by a consideration of Etna, now 11,000 feet high and 90 miles round the base. It was spoken of by Pindar, 473 B.C., as the "snowy Etna, the pillar of heaven, the nurse of everlasting frost," and has since then been dormant for several centuries at a time, so that the whole growth must have been the work of countless ages. Yet its foundations are laid upon one of the latest of all the geological formations, the Newer Pliocene, which contains over 90 per cent of existing species of shells.

Superposition, then, is the first and principal test, but is not always applicable, because the strata to be compared may be in different localities—one in England say, and the other on the Continent; in this case it could not be applied unless one were above and the other below some stratum like the chalk, which can be proved to be continuous between the two regions.

The second test, that of *organic remains*, is in a less degree affected by this circumstance, and depends on the fact that certain animals flourished only at certain periods of the past, and were preceded and followed by different ones, so that by paying attention to the gradual evolution which has gone on, and associating special forms with the strata in which they occur in any one district, that district may be used as a standard for others, and so on in ever-increasing circles.

To give an example: there are certain strata called Tertiary which all contain some proportion of existing species of shells, and a gradual increase in the number of these takes place as we ascend in the series. If, then, a stratum in England is found to contain 45 per cent of existing species, and another in France 40 per cent, the latter is presumably the older of the two, inasmuch as 55 per cent of the whole have had time to become extinct in the former case, and 60 in the latter.

The fossil remains most suitable for this purpose are those of mollusca (animals of which the mussel, oyster, and cockle are examples), for the following reasons, which are all equally important. (1) They possess hard parts, viz. the shells, which, when once buried, are only altered or destroyed under special circumstances. (2) They are low in the scale of life, and in consequence are very numerous, and capable of existing under the most varied conditions, viz. in salt or fresh, cold or warm water, at great depths or near the surface, while a large number are terrestrial. (3) They change less rapidly than higher orders of animals, and frequently outlast whole geological periods. (4) The same species are common over very distant areas, *e.g.* opposite sides of the Atlantic. (5) They comprise four classes, viz. brachiopoda, lamellibranchiata, gasteropoda, and cephalopoda, which exhibit a progressive development of organisation; and it may be said, roughly, that brachiopoda were most abundant in the oldest periods, lamellibranchiata in the intermediate ones, and gasteropoda in the newer ones.

In spite of the general tendency to improvement in the forms of life as we pass from ancient to more modern times, cases occur where a particular combination of circumstances produced a development higher than subsequent conditions could sustain; thus ammonites flourished in enormous numbers throughout the Secondary period, but died out with the Chalk, and the only modern ally of the family, the Pearly Nautilus, is simpler in organisation than they.

It may happen that the fossil contents of two strata in contiguous regions are very different, although of contemporary age; thus the shells and fishes of the Red Sea are quite distinct from those of the Mediterranean, and if strata in these two localities should afterwards come to light, their identity in age might not be suspected. In cases of this kind it is impossible to avoid occasionally falling into error, but the aid furnished by other tests will sometimes settle the matter.

Occasionally the mollusca fail to afford a sufficiently fine separation of strata on account of the longevity of the various species. Thus, in the period called Post-Tertiary, all the shells hitherto found are of living species; nevertheless, it is convenient to divide the period into two, Recent and Pleistocene, in the former of which all the quadrupeds as well are of living species; in the latter, part of them are extinct.

The test of *mineral character* is much less general than either of the two former, and may be explained as follows. In pursuing an extensive stratum longitudinally, it may happen that in one part fossils or other means by which its age may be determined are wanting, while in another part this is not the case. Here the continuity of the two parts would show that they are of the same age in spite of the lack of evidence in the former.

A fourth test, that of *included fragments,* may sometimes be resorted to in special cases; the principle of it is obvious, viz. that if a particular rock is found to contain fragments of another, it is posterior in date to the latter. An aqueous rock, for example, may contain fragments of a volcanic rock, or *vice versa,* and this circumstance will determine which is the older of the two in cases where all other tests are inapplicable.

CHAPTER V.

THE AGES OF ROCKS—(*Continued*).

WITH igneous and metamorphic rocks some of the above-mentioned tests are of no avail, and, in fact, the determination is much more uncertain with these than with aqueous rocks.

The age of a volcanic rock lying between two sedimentary deposits cannot be determined by superposition alone, for it may have been forced between them at any period subsequent to their formation. It must in all cases, of course, be posterior in date to the one on which it rests; but the overlying one must be examined to see if it bears any traces of alteration by heat; if so, the volcanic rock is posterior to them both; if not, it is intermediate in age as well as in position. In the former case it is said to be intrusive, in the latter contemporaneous or interbedded.

The test of organic remains is only applicable in the case of volcanic rocks to such as are fragmental (*i.e.* those which have fallen down from the air), and enclose leaves, shells, bones, etc., in much the same way as an ordinary sedimentary deposit. The test of included fragments is of very limited application, and has been sufficiently explained above.

With plutonic and metamorphic rocks the means are still more vague, being confined chiefly to relative position, and, in one or two doubtful cases, to included fragments; it has, however, been sufficiently demonstrated that both these classes are associated with aqueous rocks of all ages, and that their formation is not the work of any single period, but has been in progress continually.

It might at first sight seem most natural to begin by considering the oldest rocks—those which contain the lowest forms of life, and are the foundations upon which the others rest; but we shall reverse this order, following Lyell, who states his reasons thus:—"When we study the geological records of the earth and its inhabitants, we find, as in human history, the defectiveness and obscurity of the monuments always increasing the remoter the era to which we refer, the rocks becoming more generally altered and crystalline the older they are, and the difficulty of determining their true chronological relations becoming more and more enhanced, especially when we are comparing those which were formed in very distant regions of the globe. Hence we advance with surer steps when we begin with the study of the geological records of later times, proceeding from the newer to the older, or from the more to the less known.

"In thus inverting what might seem to be the natural order of historical research, we must bear in mind that each of the periods above enumerated,[1] even the shortest, such as the Post-Tertiary, or even the Pliocene, Miocene, or Eocene, embraces a succession of events of vast extent, so that to give a satisfactory account of what we know of any one of them would require many volumes. When, therefore, we study one of the newer groups before endeavouring to decipher the monuments of an older one, it is like endeavouring to master the history of our own country and that of some contemporary nations before we enter upon Roman history, or like investigating the annals of ancient Italy and Greece before we approach those of Egypt and Assyria."[1]

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[1] Referring to a table of rocks similar to the one below.

In the following pages the chief English sedimentary strata, with their more important characteristics, are presented in a tabular form in the following order, which has been determined by some one at least of the methods given above, and, where it has been thought necessary, the foreign ones are intercalated in their proper places. (In the case of the less known towns which have given their names to various strata, the counties in which they are situated are given in brackets.)

POST-TERTIARY.

Recent	Clyde marine strata. These contain canoes and other specimens of human workmanship, and are of comparatively recent origin.
Pleistocene	Kent's cavern, Torquay, and the Brixham cave (Devonshire).
	Drift of Fisherton, near Salisbury.
	Glacial drift of Scotland and North Wales.

TERTIARY.

Newer Pliocene	Bridlington drift (Yorkshire).
	Drift of Norfolk cliffs.
	Cromer forest-bed (Norfolk).
	Norwich crag.
Older Pliocene	Red crag of Essex.
	White crag of Suffolk.

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[1] *Student's Elements*, p. 119.

TERTIARY—(*Continued*).

Lower Miocene	Hempstead beds (Isle of Wight).
	Lignite of Bovey Tracey (Devonshire).
	Leaf-beds of Mull, interstratified with volcanic tuff and basalt.
	Basalt columns of Giant's Causeway (Antrim).
Upper Eocene	Several strata in the Isle of Wight, viz. at Bembridge, Osborne, St Helen's, and Headon.
	Barton clay (Hants).
Middle Eocene	Bagshot sands (Surrey).
Lower Eocene	London clay.
	Woolwich and Reading series.
	Thanet sands.

CRETACEOUS.

Upper Cretaceous	Upper white chalk, with flints.
	Lower white chalk, without flints.
	Chalk-marl.
	Upper Greensand.
	Gault.
Lower Cretaceous or Neocomian	Greensand of Folkestone, Sandgate, and Hythe, and Speeton clay (Yorks).
	Weald clay.
	Hastings sand.

OOLITE.

Upper	Purbeck beds (Dorsetshire).
	Portland Oolite (Dorsetshire).
	Kimeridge clay (Isle of Purbeck, Dorset).

Oolite—(*Continued*).

Middle	Coral rag. Oxford clay.
Lower	Cornbrash and Forest marble. Bradford clay (Wiltshire). Great or Bath Oolite. Stonesfield slate (Oxfordshire). Fuller's Earth. Inferior Oolite.

Lias.

Upper.
Middle, or Marl-stone.
Lower.

Trias.

Rhætic or Penarth beds (Glamorganshire), beds of passage between Lias and Trias.
Keuper, or Upper New Red Sandstone.
Bunter, or Lower New Red Sandstone.

Permian.

Upper Permian of Cumberland.
Magnesian Limestone of Durham and Yorkshire.

Carboniferous.

Upper	Coal-measures of South Wales. Coal-measures of North and Central England. Millstone grit.
Lower	Mountain or Carboniferous Limestone.

DEVONIAN.

Upper .	Pilton group (Devonshire).
Middle .	Ilfracombe group (Devonshire).
Lower .	Lynton group (Devonshire).

SILURIAN.

Upper	Ludlow formation (Shropshire), with bone bed. Wenlock limestone (Shropshire). Llandovery sandstone and slates (Carmarthenshire).
Lower	Bala (Merionethshire) and Caradoc beds (from a hill called Caer Caradoc, near Church Stretton in Shropshire). Llandilo flags (Carmarthenshire). Arenig group (from a mountain of that name in Merionethshire).

CAMBRIAN.

Upper	Tremadoc slates (Carnarvonshire). Lingula flags (named after the brachiopod *Lingula*).
Lower	Menevian beds (St David's, Pembrokeshire). Longmynd group (Shropshire).

LAURENTIAN.

Lower (?)	Ross-shire, Sutherlandshire, Isle of Lewis.

The five Maps which accompany the Tables show with tolerable accuracy the positions occupied by the chief formations in England; thus Map I. shows the Tertiary area, excluding the Post-Tertiary river-gravels and drifts, and the Miocene deposits; Map II. the Cretaceous area, and so on. The north-westerly direction in which the strata successively appear should be noticed, as well as the greater space occupied by the older formations. Foreign localities have only been inserted where they present some special feature of interest.

The plates of fossils do not call for any remark, as their use will be readily apprehended.

CHAPTER VI.

THE TERTIARY PERIOD.

IN the earlier days of geological science the granites, slates, and other igneous and metamorphic rocks were called Primary, because they were (erroneously) supposed to be in all cases the oldest rocks of which we had any knowledge, and to serve as the foundations on which the Secondary or fossiliferous formations were laid, while alluviums, drifts, river-gravels, etc., were called Tertiary. These names are still retained, but with extended meanings, which will be made clear as we proceed. They have been substituted to some extent by the words Palæozoic, Mesozoic, and Cainozoic respectively, but there is no advantage to be gained by the use of these latter.

The division between the Secondary and Tertiary periods is intended to be perfectly definite, viz. that the latter must contain some proportion, however small, of living *species* of shell-fish;[1] but in one or two cases undoubted Tertiary strata occur in which they have not yet been discovered.

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[1] Shell-fish, in common with the rest of the animate creation, are called in scientific language by two names, the generic and specific, which may be compared to the surname and christian name respectively of human individuals. Thus the generic name *Felis* comprises the lion, tiger, lynx, leopard, etc., but by adding the specific names *leo*, *tigris*, *lynx*, *pardus*, etc., there is no room for ambiguity, while the connection between them is sufficiently expressed by the use of the same generic name for each. Hence the range of a species is in all cases less, both in time and space, than that of the genus to which it belongs.

Between the Primary and Secondary periods the division is more arbitrary, and depends on the affinities of the fossils of a doubtful stratum with those of undoubted Primary or Secondary strata. The lowest members of the Trias (Secondary) and the highest of the Permian (Primary) are generally unfossiliferous red sandstones, which it is difficult or sometimes even impossible to assign to their proper places, but it is not a matter of any great consequence.

A fourth period, the Post-Tertiary, has been added to include the strata which contain 100 per cent of living species of mollusca, and it has even been found necessary to subdivide it into two, the Recent and Pleistocene, as mentioned above.

The latest of the Recent deposits of any importance are the peat-mosses of Denmark, which contain implements of iron, bronze, and stone, along with branches and trunks of several kinds of trees, especially the beech, oak, and Scotch fir. The beech is a tree which now flourishes abundantly in Denmark, and has done so for the last 1800 years; the Scotch fir not only does not grow there of itself at present, but cannot be persuaded to do so by horticulturists, so thoroughly has the country become unsuited to it. As for the oak, two varieties of it are found in the peat-mosses, one in which the leaf was supported at the end of a long foot-stalk, hence called the pedunculated[1] oak, the other in which the leaves had scarcely any foot-stalk, the sessile oak. Iron tools are found about as far as the beech trunks; below them bronze tools descend through the first oak, and about half-way through the second; and lastly, the stone implements are associated with the Scotch fir. As it probably takes at least 2500 years for a tree to establish itself in any country and to become extinct, we are here carried back at the very threshold of our observations far beyond the historic period, and no single fact hitherto discovered at all tends to diminish this prospect, but only to increase it.

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[1] The meanings of this and other technical words will be found in the Glossary.

The Danish kitchen-middens consist of mounds of shells of edible molluscs such as the oyster, cockle, and periwinkle, along with kitchen-refuse, broken weapons, etc. They are of various lengths, from 100 to 1000 feet, in height from 3 to 10 feet, and one of them is as much as 200 feet broad. They probably belong to a somewhat earlier epoch than the peat-mounds, for no implements of metal have been detected in them, only stone, horn, bone, or wood.

The successive ages of Iron, Bronze, and Stone are also traceable amongst the articles dredged up from some of the shallower parts of the Swiss lakes (*e.g.* Geneva, Constance, Zurich, and Neuchâtel). The mud in the same spots contains numerous wooden piles, now decayed at their upper extremities, and which doubtless served to support the dwellings of the inhabitants. Human bones have not hitherto been discovered in them, but this fact appears much less significant when we reflect that neither have they ever been dredged up from the sea-bottom in scientific exploring expeditions, nor were they even met with after the Lake of Haarlem was drained some years ago, although frequent shipwrecks had taken place on it. (Lake-dwellings belonging to the Bronze and Stone Ages are found in English, but especially in Irish, peat-bogs, and are called *crannoges.*) All the stone implements hitherto alluded to are of the later or Neolithic type,—that is to say, they have been fashioned and trimmed with some care—occasionally, indeed, with great skill. There was a time before this, however, when men were content to have ruder weapons which will not bear comparison as works of art with the later ones, either as to shape or finish. To this age is given the name Palæolithic, and its antiquity is shown by the numbers of bones of extinct quadrupeds associated with it.

The human relics are mostly found in caves and river-gravels; the chief English localities are Brixham and Torquay in Devonshire, Wookey Hole near Wells in Somersetshire, Herne Bay, Swale Cliff near Whitstable in Kent, Bury St. Edmunds, the caves of the Gower peninsula in South Wales, and the valleys of the Thames and Ouse. Numbers of them are also found on the Continent; for instance, at Abbeville and Amiens on the Somme, at Mentone, at Neanderthal near Düsseldorf on the Rhine, at Liége in Belgium, in Southern France, and at Mont Salève near the Lake of Geneva. In the Mentone cave a complete skeleton of a man, six feet high, was found, and another in the Neanderthal cave of smaller dimensions. The relics of man (other than bones) comprise flint or stone arrow-heads, lance-heads, hatchets, and other weapons; handles of bone, horn, ivory, or stone, some of these with rude drawings of animals cut into them; fragments of charcoal and pottery. With them are associated bones of quadrupeds, which may be classified as follows:—Extinct altogether: cave lion, cave bear, cave hyæna (larger than the existing lion, bear, and hyæna), mammoth, early elephant (*Elephas primigenius*), fossil horse, Irish elk, woolly rhinoceros, and great hippopotamus (*H. major*). Wanting in this country, but found in others:

leopard, lynx, grisly bear, glutton, lemming, auroch, musk-ox. Still living in this country, or only recently banished: fox, otter, badger, hare, horse, wolf, beaver, wild boar.

The first appearance of man is thus carried back to a time when England was connected with the Continent, for large quadrupeds are not developed in small islands, neither is it probable that England was the first home of mankind. Abundant evidence of the antiquity of the period is also furnished by the river-gravels containing flint implements, so numerous in various parts of the world; these gravels occur at different heights on the sides of a valley, and the higher ones are older than the lower, for the obvious reason that the nearer any one is to the present position of the river-bed, the more recent is the date of its formation.

The Palæolithic age appears to have been preceded by a most remarkable period, when not only the British Isles, but a great part of Northern Europe and America, was covered with sheets of ice, much in the same way as Greenland is now; when arctic animals roamed down to temperate latitudes, and arctic shell-fish lived in the adjoining waters. The evidence on which such a statement is made may be summed up as follows. In Europe north of lat. 50°, and in America north of lat. 39°, a fine, tenacious, unstratified, unfossiliferous clay is found very plentifully distributed, and in it are many stones of all sizes and composition, mostly striated with parallel lines in the direction of their length; the colour of the clay is usually that of the rocks in the district where it occurs, so that it is red in a district of Red Sandstone, white in a Chalk district, and so on; the stones generally belong to the same region, though occasionally they have been carried a hundred miles or more. This boulder-clay or "till," as it is sometimes called, is very plentiful in Scotland, the north of England, and North Wales; it rests directly on the rock-surface underneath, and is covered in many places by superficial deposits of sand, gravel, or drift having a similar origin. It is accompanied by confused heaps of stones, huge isolated blocks, and rounded hummocks of rock which look from a distance like a flock of sheep lying down, and are hence called "roches moutonnées." All these appearances, without exception, are found in countries like Switzerland and Norway, where glaciers abound, and can be seen in process of formation there; and no other explanation can be given, or need be sought for, than that which assigns their production in other countries to the same cause.

Underneath a glacier or an ice-sheet the motion and pressure combined grind up the rocks into a fine clay or mud, which is of course unstratified and unfossiliferous; a mass of stones called a "moraine" is carried along at each side and deposited at the end, while huge fragments of rock are buried in the ice and borne many miles from their original source. The dimensions of some of these erratic blocks are enormous; one in particular, called the Pierre-à-Bot, lying on the slope of the Jura, 900 feet above the Lake of Neuchâtel, is a mass of granite supposed to weigh about 3000 tons, and to have been brought from the Alps on the other side of the country during the Ice Age.

Though the boulder-clay itself is unstratified, it sometimes contains intercalated beds of gravel or sand which have a most important significance, as they contain bones of the mammoth and reindeer, showing that the glaciation was occasionally interrupted during times when these creatures could penetrate into previously forbidden districts.

The causes of such an abnormal state of things were in all probability partly astronomical and partly geographical. The earth moves round the sun in an ellipse, so that at certain seasons of the year the distance between the two is greater than at others. At the present time winter occurs in the northern hemisphere when the distance is least, and in consequence the season is shorter and warmer (so far as it depends on the earth's orbit alone) than in the southern; but there are causes at work whereby in about 10,500 years the reverse will be the case, and our winter will then be longer and colder than at present, and the summer shorter and hotter. Nor is this all; the shape of the earth's orbit is continually changing, being at one time most nearly circular, at another most elongated, so that the difference between the greatest and least distances of the sun varies from 2½ to 10½ million miles. With the latter difference the summer would be no less than twenty-eight days longer than the winter in one hemisphere and shorter in the other, and every 10,500 years there would be alternations in each hemisphere of very long and cold winters with short and hot summers, and of short mild winters with long cool summers. This would account for the mild inter-glacial periods above referred to, when the cold was less severe, though they would not necessarily recur at every such interval for reasons which need not be explained here. It might be imagined that a short hot summer would undo the effect of a long cold winter, but this is not the case, for the sun's light and heat are both largely reflected from the white surface of snow; moreover, a great deal of heat has to be expended in simply melting it, before its temperature can be raised at all.

Warm air has certainly a great effect on snow, but dry air is not warmed by the passage of the sun's rays through it any more than a pane of glass is; it is only moist air which stops the rays, and thereby becomes heated itself. It is a frequent observation in the Alps and elsewhere that though the direct sunshine is powerful enough to peel the skin off one's face, the air is at the same time exceedingly cold, and the difference between the sunshine and shade temperatures correspondingly great. So again, when a fire is first lighted in a cold room, the vapour from one's breath can be traced quite close to the bars, so close in fact, that the hand can scarcely be held where it finally disappears, but after the air has become warm, it vanishes at once in all parts of the room. Cold, then, can be extensively stored up, if the expression may be allowed, in snow and ice, while heat is incapable of being similarly stored either in land or water; in fact, the more these are heated the more they tend to part with their heat.

As to the geographical causes, it is well known that the climate of Europe is very greatly ameliorated by the Gulf Stream, and that a deflection of this current through the Isthmus of Panama or along the east coast of North America would produce untold effects in lowering our mean annual temperature.[1]

A combination of these causes then—winter in the northern hemisphere, when the earth is at its greatest *possible* distance from the sun, along with a rearrangement of ocean-currents and of land-areas—may be considered sufficient to account for a Glacial epoch, and also for the mild climates which prevailed several times during its continuance, when the mammoth, hippopotamus, and reindeer could exist for several thousand years together in the previously and subsequently glaciated districts of England and Scotland.

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[1] For a more detailed explanation of the causes of Glacial epochs, see *Island Life*, chap. viii.

Again, a reversal of the above conditions would also account for the mild arctic climates of the Miocene and Cretaceous eras, while we are not obliged to assume that Glacial periods have occurred regularly throughout all geological time, for the geographical tendencies may have conflicted with the astronomical or *vice versa*. As a matter of fact, indications of ice-action have been detected in the Lower Permian conglomerates and breccias of Worcestershire and Shropshire, also in the Carboniferous formation in Scotland, Europe, and North America, and even in the Silurian of the latter country.

From the predominance of lakes in northern regions in places where glaciation can be proved to have gone on, it has been supposed by some that their basins were scooped out by the ice; but though this may have been the case in some instances, their origin cannot well have been due to this cause alone, for they are wanting in the neighbourhood of Turin, where some of the largest Alpine glaciers used to exist, and also among the Caucasus mountains, where glaciers are still plentiful.

Pliocene Period.—In Yorkshire, Norfolk, and Suffolk superficial deposits of clay and sand occur, in which the mollusca are not all identical with living species, and which are therefore referred to the Pliocene period. The deposits still have a glacial character, and contain fragments of the more ancient chalk and flints; they are spread over a large part of Norfolk and Suffolk, but have been omitted from the map on account of their superficial nature. Marine shells of the same age are found at heights of 1000 to 1200 feet near Dublin, so that in the early part of the Glacial period a depression to this extent must have taken place, followed by an elevation in which England was connected with the Continent to allow various quadrupeds access to the country. Numerous arctic shells are found in the Newer Pliocene strata, but they begin to have a more southern aspect as we approach the Red and the Coralline Crag of the Older Pliocene.

The **Miocene** period is not well developed in England, or even in the British Isles, but presents many interesting features on the Continent; the Upper Miocene of Œningen (between Constance and Schaffhausen in the valley of the Rhine) contains an extraordinary number of tropical plants, mostly allied to North American species, and of insects whose character is more European and less tropical.

The Lower Miocene of Southern France (departments of Puy de Dôme, Cantal, and Ardèche) furnishes lacustrine strata, but more especially a large number of extinct volcanoes, with lava-streams, basaltic columns, etc., which have been exposed to no denudation except atmospheric since the date of their formation.[1]

The lignite beds and clays of Bovey Tracey in Devonshire are of considerable interest, as they contain numerous seams of vegetable remains comparable with those of Switzerland and Germany; in fact, their age has been determined entirely in this way, owing to the absence of other fossils.

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[1] See Geikie, *Geological Sketches.*

In Antrim there occur Miocene volcanic rocks with interstratified beds containing leaves of beech, oak, plane, and conifers; they are supposed to be of the same age as a large series of basalts and lavas in the Hebrides, *e.g.* the Isle of Eigg, Fingal's Cave in the Isle of Staffa, etc.

The **Eocene** strata in England lie in two basins, the London and the Hampshire, which were probably once continuous, as small outlying patches of them occur between Salisbury Plain and the Weald; they lie unconformably on the Chalk, and are of small thickness in comparison with their area,—in other words, they resemble saucers much more than basins. The London Clay is the most important member of the group: in the Isle of Sheppey it yields numbers of fruits and seeds of palms, gourds, melons, and acacias, indicative of a warm climate and of the contiguity of land—a conclusion borne out by the discovery in it of bones and teeth of crocodiles, turtles, birds, and mammals.

These must all have lived before the growth and development of many European and Asiatic mountain chains, for nummulites, which enter largely into the composition of the Alps, Pyrenees, Carpathians, and Himalayas, are unknown to the Lower Eocenes.

A great interval of time is unrepresented between the Eocene and Cretaceous formations, not a single species of mollusca being common to the two.

Recent and Pleistocene. **POST-TERTIARY.**

	BRITISH.	FOREIGN.	CHARACTER.	CLIMATE.
Recent. Shells and mammalia all of living species.	(Clyde marine strata.)	Kitchen-middens of Danish islands in the Baltic.	Mounds of shells of oyster, cockle, periwinkle, and other edible molluscs, with bones of wild quadrupeds. No metallic articles.	Temperate.
		Swiss lakes.	Pile-dwellings, 15 or 20 feet below present surface, first explored in 1854 in Lake Zurich.	Colder.
Pleistocene. Shells recent, mammalia in part extinct.		S. of France (Reindeer period).		
	Devonshire (Brixham, Torquay). Salisbury. Glacial drift of Scotland and N. Wales.	Amiens, Liége. Australia. New Zealand.	Cavern deposits or valley gravels.	Growing colder.
		Rhine valley.	Fluviatile loam or loess.	
		Northern Europe.	Glacial drift.	Very cold.

Summary.—All the mollusca are of living species ; in the next period (Pliocene) part of
Danish kitchen-middens resemble heaps of shells left by the Red Indians of North
lakes are made by several races of modern savages. Post-tertiary deposits are scattered
climate of Pleistocene somewhat conflicting ; Cyrena fluminalis and Unio littoralis now
of the mammals were doubtless inhabitants of colder regions, such as Norway and Finland.
causes, and was interrupted at intervals of 10,000 years or so by warmer spells.

POST-TERTIARY.

Fossils.		General Remarks.
Entirely of species now living.	*Neolithic.*	Traces of man abundant, knives, hatchets, pottery, and charcoal.
	Actual human bones, though sometimes found, are rare, possibly because it was the custom to burn the dead.	Implements made by human hands in stone and bronze. *Stone* implements associated with deer, wild boar, wild ox; *bronze* implements with domestic ox, goat, and pig. Wheat and barley are also found, and iron weapons occasionally.
Cave lion, leopard, lynx, cave hyena, cave bear, wolf, fox, otter, badger, hare, beaver, mammoth, horse, Irish elk, red deer, reindeer, musk-ox, rhinoceros, hippopotamus, wild boar, and others. Small land and fresh-water shells; helix, pupa, succinea.	*Palæolithic.*	Man shown to be contemporary in Europe with animals, some of which are not now inhabitants of that continent, others are quite extinct. Stone implements of a rude type; the physical geography of Europe different from that now prevailing—*e.g.* valleys have since become wider and deeper, lines of drainage have changed, and limits of land and sea become different. Flint implements numerous.
Mostly arctic; Astarte, Saxicava, Leda, Tellina.		Proofs of glacial action abundant; erratics, moraines, fine clay without fossils, roches moutonnées. Probable extent of submergence 2000 feet, making British Isles an archipelago. Many European lakes were excavated by glaciers. Boulders found as far south as 50° N. lat. in England, 40° in America.

them are extinct. Palæolithic deposits were formed at the close of the Glacial period. The
America on the eastern shores of the United States. Pile-dwellings like those of the Swiss
for the most part, and not traceable over wide areas like older formations. Evidences as to
inhabit warmer waters, such as the Nile, the Seine, and Loire; many other shells and most
The Glacial period was probably due to a combination of astronomical and geographic

Pliocene. **TERTIARY**

	BRITISH.	FOREIGN.	CHARACTER.	CLIMATE.
Newer. Shells almost all of living species.	Bridlington.		Sand and clay, otherwise known as drift.	Warmer than in th preceding period.
	Norfolk cliffs.		Clay and sand, derived from waste of chalk.	
	Cromer.		Forest bed, traceable as far as Kessingland, 40 miles round the coast.	
	Norwich.		Crag; an estuarine deposit of sand, loam, and gravel.	
		Sicily, especially the central and eastern parts.	Marine strata, sands, clays, and basalts.	
		Val d'Arno.	Sands and conglomerates.	Temperat to warm.
Older. Extinct shells forming a large minority.	Essex.		Red crag, resting on London clay.	
	Suffolk.		Coralline crag.	

Summary.—The Pliocene period in England is developed chiefly in the eastern parts, an thin, hence superposition fails as a test of age, and the organic remains have to be relie of shells.

TERTIARY.

Fossils.	Thickness.	General Remarks.
Elephant, rhinoceros, deer, horse, hippopotamus, beaver. Tellina, Trophon, Ostrea, Arca, Avicula, Cardium, etc.		Glacial clay and boulders still found, the age of which, as indicated by the shells, is anterior to the Glacial epoch.
	Up to 200 ft.	
Land and fresh-water shells; cones of Scotch fir; elephant, rhinoceros, horse, beaver, deer.		Exposed between high and low water mark, an estuarine deposit. A subsidence to the extent of 400 or 500 feet must have taken place, followed by an elevation of equal amount.
Mastodon, elephants, deer; Pholas, or rock-borer, Barnacles, Rhynchonella, Astarte, Nucula, Tellina, Cardium, Turritella.	20 ft.	Called also Fluvio-marine Crag.
	3000 ft.	More extensive than in any other part of Europe. The growth of Etna, 11,000 feet high and 90 miles round the base, has taken place since Newer Pliocene times.
Mastodon, elephant, rhinoceros, hippopotamus, bear, hyena; with pine, oak, alder, plum, laurel, walnut.		
Limpet, Pholas, Purpura tetragona, Voluta lamberti, Trophon antiquum, with mammals.	20 ft.	
Astarte, Pyrula, Fascicularia, oysters, mussels, cockles, and other existing shells.	20-30 ft.	Cold appears to have gone on increasing, with some oscillations of temperature, from the time of the coral-line to that of the Norwich Crag.

comprises the crags. The deposits, both British and foreign, are local and comparatively
on. Strata are called Pliocene when they contain 50 or more per cent of existing species

	BRITISH.	FOREIGN.	CHARACTER.	CLIMATE.
Upper.	Wanting.	Touraine.	Faluns, *i.e.* shelly sand and marl, like our crag.	Sub-tropica
		Œningen, near Lake Constance.	Marls and limestones.	Tropical.
		Siwalik Hills (south of the Himalayas).	Sandstone, clay, shingle, and marl.	Tropical.
Lower.		Central France.	Volcanoes and volcanic dust, cinders and lava.	
		Greenland, Iceland, and Spitzbergen.	Sandstones and marls.	Temperate.
	Hempstead, I. W.		Sands, clays, and marls.	
	Bovey Tracey (South Devon).		Decomposed and worn granite, with much vegetable matter.	
	Isle of Mull.		Leaf-beds covered with basalt and ashes.	
	Antrim (Giant's Causeway).		Basalt columns.	

Summary.—Miocene deposits, in common with most Tertiary beds of North-western Europ Vast deposits, however, occur in Southern Europe, North Africa, Asia, etc. Those and the Siwalik Hills,—the former remarkable for plant and insect, the latter f age. Extinct shells form from 75 to 82 per cent of the whole.

TERTIARY.

Fossils.	Thickness.	General Remarks.
Dinotherium, mastodon, rhinoceros, dolphin. Cones, mitres, volutes, olives.	50 ft.	
Extraordinary profusion of plants: vine, walnut, maple, poplar, cinnamon, magnolia, and conifers; insects in great number and variety.	30 ft.	
Great numbers of mammals, hippopotamus, pig, mastodon, elephas, monkey, giraffe, camel, stag, antelope, also crocodiles and turtles.		
Mastodon, elephas, rhinoceros, tapir, bear, hyena.		The Alps were at this period much lower than at present; fossil palms, which must have grown near the sea-level, are found at heights of 2000 feet.
Beech, oak, plane, poplar, maple, walnut, lime, magnolia.		
Corbula, Cerithium, Cyrena.	170 ft.	
Only plants: ferns, oak, laurel, fig. ;	300 ft.	Supposed to be Miocene by a comparison of the flora with that of Switzerland.
	130 ft.	
	540 ft.	

are local and wanting in the extension and thickness characteristic of older formations.
the British Islands are very feebly developed; the most notable foreign ones are at Œningen
mammalian life. The most recent traces of volcanic action in Great Britain are of Miocene

Eocene. **TERTIAR**

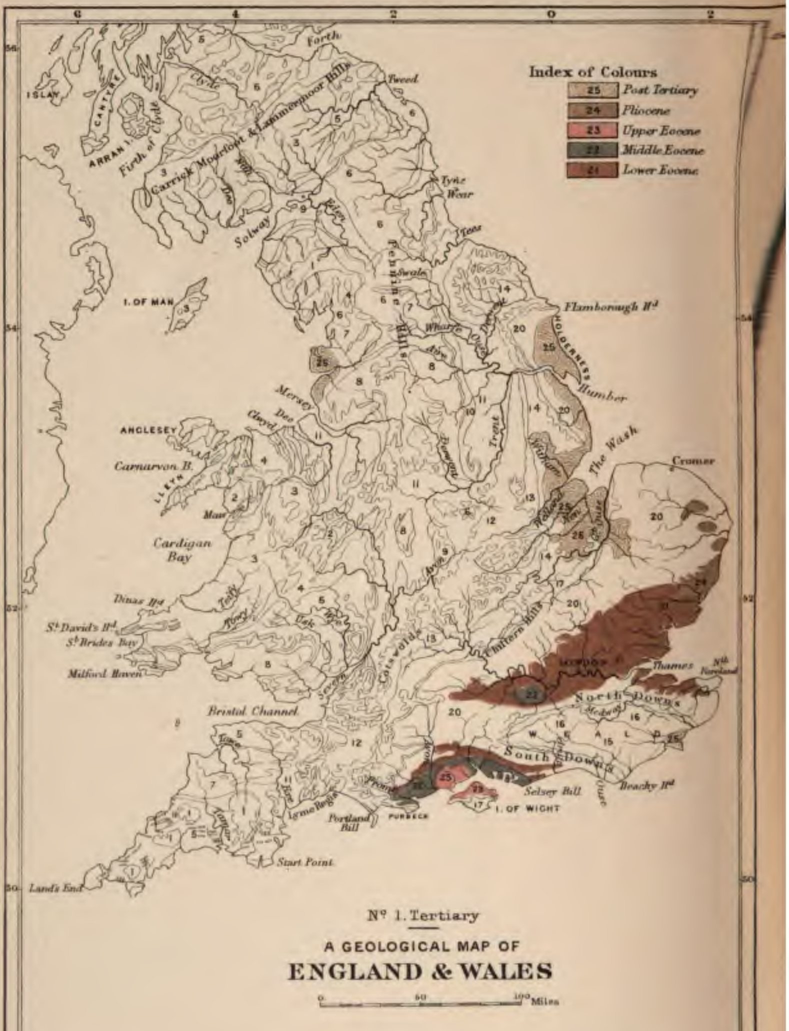
	British.	Foreign.	Character.	Climate.
Upper.	Isle of Wight—freshwater and marine deposits.		Marls, clays, limestones, flags.	Temperat to warm
	Barton clay.		Clay and sand.	
		Paris.	Gypsum and marl, constituting the Paris basin.	
Middle.		Europe and Asia.	Nummulitic limestone.	
	Bagshot sands.		Sand and clay.	
Lower.	London clay.		Brown, dark-blue, or black clay, a deep-sea formation.	Warm.
	Woolwich and Reading beds.		Clay and sands.	
	Thanet sands.		Sand, resting on chalk, with flints and rolled flints.	
		Paris.		

Summary.—Freshwater and marine strata are both numerous. Fifty-one species of mammal
whole. Four of the chief capitals of Europe—viz. London, Paris, Vienna, and Brussels–
of Wight. The Woolwich and Reading series and the Thanet sands are sometime
Nearly all Oceanic islands, except New Zealand and the Seychelles, are of Tertiar
Islands, the Japan Islands, Vancouver's Island, and New Zealand; also in German

TERTIARY.

Fossils.	Thickness.	General Remarks.
Cerithium, Cyrena, Arca, Mytilus, Planorbis, Limnæa, Palæotherium, turtles, birds.	280 ft.	A prevalence of more southerly forms of shells and quadrupeds amongst the Eocene strata in general.
Typhis pungens, Voluta athleta, Terebellum, Cardita, Limnæa, Nummulites.		
		Found in the Alps 10,000 feet above the sea-level, in Western Thibet, 16,500 feet. It stretches eastward from Switzerland across Europe, through the Carpathians, and thence by Persia and the Himalayas as far as the frontiers of China.
Nummulites, Chama squamosa, Crassatella, Dentalium, sharks' teeth, crocodiles.	1270 ft.	Furnishes pipe-clay.
Fossil fruits of palm ; crocodiles, turtles, birds, and mammals ; fishes' teeth, Voluta, Nautilus.	500 ft.	Contains the septarian limestone used for making Roman cement. This clay is more ancient than almost the whole of the Alps, Pyrenees, Carpathians, or Himalayas.
Goniaster, Cyrena, Nucula, Pholadomya, Aporrhais, Cerithium, Voluta, Nautilus, crocodiles and turtles, birds and mammals.	90-160 ft.	Fluviatile beds underlying deep-sea strata. Land drained by the ancient river at whose mouth these deposits were formed, appears to have been to the S.W. of London.
	90 ft.	
		English Eocene strata are almost entirely mechanical, the Paris beds largely chemical.

have been described. The proportion of extinct shells is from 95 to 100 per cent of the
are situated on Tertiary strata; in England there is a second basin in Hampshire and the Isle
called the Lower London Tertiaries, but the same beds also occur in the Hampshire basin.
age. Coal-fields of this period occur in India and the Indian Archipelago the Philippines
and Austria.



Nº 1. Tertiary

A GEOLOGICAL MAP OF

ENGLAND & WALES

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CHAPTER VII.

THE CRETACEOUS PERIOD.

THE Upper Cretaceous group is separated from the Eocene by marked mineralogical and palæontological characters; calcareous strata taking the place of arenaceous and argillaceous ones, and the molluscan fauna of the two being quite different. The most conspicuous member of the group is the White Chalk, from which the name Cretaceous is derived (Lat. *creta*, chalk); it occupies a large space in England, where it is divided into an upper series containing the siliceous nodules known as flints, and a lower in which these are absent.

Its composition is mainly carbonate of lime (94 to 99 per cent); the rest is chiefly silica, alumina, or carbonate of magnesia. It was thought to be a profoundly oceanic formation, inasmuch as it closely resembles in appearance the ooze found on the floor of the Atlantic, Pacific, and Southern oceans at depths up to 3000 fathoms; but in chemical composition it is more allied to the ooze from lesser depths, besides which the mollusca are of a shallow-water character; so that, on the whole, we must suppose it to have been formed in a sea not more than a few thousand feet deep.[1]

Underneath the Lower White Chalk appears a calcareoargillaceous formation called the Chalk Marl; it presents no special features of interest, and is succeeded by the Upper Greensand. This latter was called the Chloritic series (Gr. *chlōros,* green) by Sir Charles Lyell, to avoid the use of the term Greensand, formerly applied to the whole group of Lower Cretaceous strata as well as to this particular member of the Upper; the term is, besides, a misnomer, for green grains are the exception, not the rule. It contains a large number of reptilian remains—Pterodactyl, Ichthyosaurus, Pliosaurus, and Chelonians—and includes the coprolite beds of Cambridge and of Farnham in Surrey, so extensively used in the production of artificial manure.

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[1] *Island Life*, chap. vi.

Next in order follows the Gault, a stiff blue clay which attains a thickness of about 400 feet, and is largely used for making bricks. The fossils in it are often beautifully preserved, having been well shielded from atmospheric influences.

The Upper Cretaceous rocks of Southern France, Spain, and Greece are characterised by a remarkable order of Lamellibranchs called *Rudistes,* of which *Hippurites* is one genus; they are not only extinct, but have no analogues at the present day. At Aix-la-Chapelle an extensive flora has been discovered, in which the great divisions of the vegetable kingdom exist in nearly the same proportion as at the present day; while in all earlier floras this is by no means the case, flowerless plants being in a great majority.

The Lower Cretaceous formation comprises a marine and a freshwater series, to the former of which belong the Greensand of Folkestone, Sandgate, and Hythe, and the Speeton clay in Yorkshire, and several clays and sands of minor importance, altogether about 600 feet thick, and each characterised by peculiar species of fossils. Underneath these marine strata lies a freshwater formation known as the Wealden, from 1600 to 2000 feet thick, probably deposited in the delta of a great river. The Iguanodon, so called from the resemblance of its teeth to those of the Iguana of Central America and the West Indies, was a great herbivorous reptile characteristic of this series.

The Hastings sand, altogether about 1000 feet thick, is subdivided into four groups of clays and sands, not separable by any marked distinctions from the Weald clay except in the preponderance of sandy strata.

An extensive sub-tropical flora of the Lower Cretaceous period has been discovered in Greenland and Spitzbergen, showing that a warm climate extended within 12° of the pole, a state of things which was repeated in Miocene times.

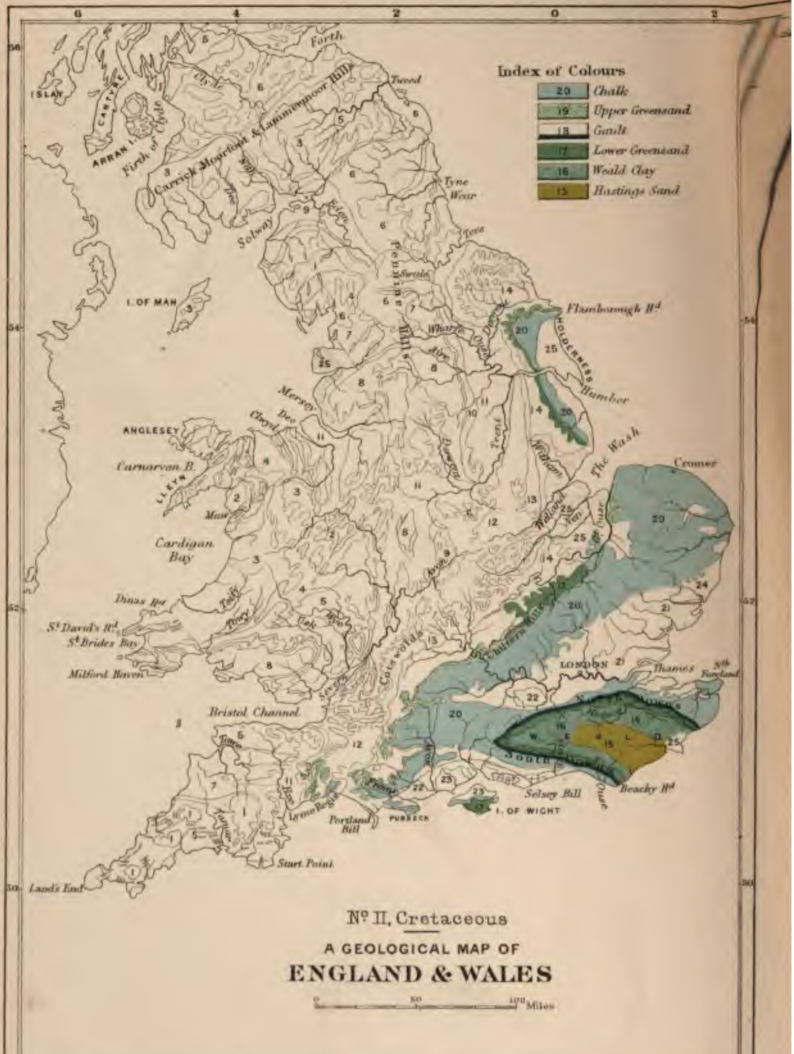
	BRITISH.	FOREIGN.	CHARACTER.
These and the succeeding strata as far as the Gault form the **Upper Cretaceous.**		Maestricht (on the Meuse). Faxoe. Denmark.	Calcareous.
Upper White *Chalk*, with flints.	Norfolk, Suffolk, Cambridge, Hertford, Berks, Bucks, Kent, Surrey, Sussex, Dorset, Wilts, and Hants.		White and calcareous ally too soft for b purposes. Contain and potstones, proba remains of siliceous s Boulders and pebbl been found in the England, which mu been deposited by ice.
Lower White *Chalk*, without flints.			
Chalk-Marl.			
Upper Greensand.			Sometimes contains grains, whence the The Cambridge c bed belongs to this
Gault.		Very extensive (see general remarks).	Dark-blue marl.
Lower Greensand or Neocomian, including the Wealden.	Folkestone, Sandgate, and Hythe, marine.		Sand, clay, and marl.
	Weald clay. Hastings sand, fresh-water.		Clay and sand.
		Greenland.	

Summary.—A great interval exists between the Cretaceous and Eocene, only partly fil through the Cretaceous rocks in and around London come suddenly on Palæozoic South Downs, the one going along the upper Kentish coast, the other terminat

SECONDARY.

Fossils.	Thickness.	General Remarks.
A mixture of Cretaceous genera, *e.g.* Baculites, Hamites, and Belemnites, with Tertiary genera, Voluta, Cypræa, Fasciolaria.	100 ft. More than 40 ft.	Intermediate between Cretaceous and Eocene.
Shells of Foraminifera, Galerites, Ananchytes, Terebratula, Rhynchonella, Inoceramus, Ostrea vesicularis, Lima spinosa, Pleurotomaria, Ammonites, Baculites, Belemnites, Hamites, Scaphites, Turrilites, remains of fish and reptiles; no mammals.	1000 ft. 600 ft.	The Straits of Dover form a very trifling interruption of the continuity of the chalk, which extends from England beyond Paris. Composition mainly carbonate of lime, resembling deep-sea ooze, but containing less silica. Fossils eminently marine; industrial products, chalk, marble, flints, sands, and firestones. Extends from the north of Ireland to the Crimea, a distance of 1140 geographical miles, and from the south of Sweden to the south of Bordeaux, 840 geographical miles. Covers more ground in England than any other single group. A warm climate prevailed even in the Arctic circle, as shown by the Lower Cretaceous Greenland flora, thus forming a marked contrast to the cold climate of temperate latitudes in Pleistocene times. The Upper Cretaceous flora of Aix-la-Chapelle shows that the introduction of many modern types of trees took place at this time, a conclusion borne out by the lignitic series of North America.
Numerous echinoderms; Rhynchonella, Terebratula, Exogyra, Pecten quinquecostatus, Pectunculus, Trigonia.	Together, upwards of 400 ft.; in all, 2000 ft.	
Gervillia, Nautilus, Trigonia, Diceras.	230 ft.	
	600 ft.	
Entire absence of marine fossils, but instead Paludina, Unio, Cyrena, with Iguanodon, ganoid and placoid fishes. Extensive flora belonging to a sub-tropical climate.	1000 ft.	A deposit in water of moderate depth, often very shallow; probably estuarine, or the delta of a large ancient river. Derives its name from the Wealds or Wolds of Sussex. "Neocomian" is derived from *Neocomum*, Latin for Neuchâtel.

by the Maestricht and Faxoe beds and the Pisolitic limestone of France. Borings sunk
The main band of chalk divides eastward of Salisbury Plain into two branches, the North and
Beachy Head. Between these two branches lies the Wealden.



Nº II, Cretaceous

A GEOLOGICAL MAP OF

ENGLAND & WALES

Stanford's Geograph¹ Estab¹ London

beds within a space of 500 square yards, and only a few inches deep, was a matter of great interest. Since then mammals have been found in the Trias of Somersetshire (near Frome) and of North Carolina, while none have yet been discovered in Primary strata.

The Portland Oolite, next in order to the Purbeck, is largely used as a building-stone; below it lies the Kimeridge clay, so called from a village of that name to the west of St. Alban's Head in Dorsetshire; it becomes carbonaceous in some parts, and even passes into an imperfect coal.

In the slate of Solenhofen in Bavaria a fine specimen of a reptile-like bird, called *Archæopteryx macrura*, was discovered in 1861, and is now in the British Museum; it was about the size of a crow, and differs from all existing birds in that the tail-feathers were united to twenty successive vertebræ instead of to the last one only, besides which the creature was provided with teeth, indicating a link between the classes *Aves* and *Reptilia*. Other toothed birds have since been discovered, viz. the *Ichthyornis dispar* and the *Hesperornis regalis*, belonging to the Cretaceous series of America; in the latter the teeth are not in sockets, but in grooves as in the Ichthyosaurus; it was about 6 feet high, while the other was very much smaller.

The Coral Rag consists in part of continuous beds of fossil corals, whence the name; it occurs in Dorsetshire, Wiltshire, Oxfordshire, and Yorkshire, and is subject to great variations in thickness and character. Below it comes the Oxford Clay, no less than 500 feet thick in places, and containing crystals of selenite, a form of sulphate of lime, and numerous remains of cephalopods (ammonites, belemnites, etc.), and of reptiles such as Pliosaurus, Megalosaurus, etc.

The highest member of the Lower Oolites is the Cornbrash, so called from being of a "brashy" or easily broken nature, good for corn-land; it passes down into the Forest Marble of Wiltshire, which is replaced by a mass of clay at Bradford near Bath.

The Great or Bath Oolite is much used as a building-stone; at its base lies a slightly oolitic shelly limestone, the Stonesfield slate, which, in addition to four species of mammals, has also yielded a number of bones belonging to a huge reptile, the Cetiosaurus or whale-lizard, whose thigh-bone is 5 feet 4 inches in length, vertebræ 9 to 11 inches in diameter, with ribs, etc. in proportion, so that the creature must have been about 50 feet long and 10 feet high.

Between the Great and Inferior Oolite in the west, but not in the north of England, lies a band of Fuller's Earth about 80 feet thick; its characteristic fossil is the small *Ostrea acuminata.*

Lastly, the Inferior Oolite appears conspicuously near Cheltenham, and furnishes building-stones of some little importance, and a "ragstone" used for burning into lime.

The Liassic period contains about 2000 species of mollusca, of which more than a sixth are ammonites; other cephalopoda are far from rare, but the most remarkable of the organic remains are those of huge reptiles, alike extraordinary for number, size, and structure. The Ichthyosauri are known to be upwards of 24 feet long, and provided with anterior paddles like a whale or porpoise; they had enormous eyes and a formidable array of teeth, and were doubtless carnivorous aquatic animals. Some specimens from Lyme Regis in Dorsetshire have been so perfectly preserved that the half-digested remains of fishes and reptiles can be detected within their skeletons. The Plesiosauri were also of great size, and resembled the preceding in general structure; the neck was, however, very much longer, and the head very much smaller. The Pterodactyl is no less remarkable; it was an undoubted reptile, though capable of flying like a bat; its hand contained four digits (and not five, as usually represented), of which the outer one was of such exaggerated dimensions that the creature's breadth, when expanded, was very much greater than its length. Most of its bones were hollow like those of existing birds, while in modern bats this is not the case. The range of the three preceding orders in England is from Lower Lias to White Chalk, though in Germany the two former are found in the Trias.

The Triassic or New Red Sandstone contains at its summit or close certain "beds of passage" called the Rhætic or Penarth beds, about 100 feet thick, which contain numerous species of fish and saurians. These deposits are very local, however, and are succeeded in descending order by a great series of red loams, shales, sandstones, and conglomerates, resembling a similar series, found underneath the Permian and Carboniferous formations, called the Old Red Sandstone. It is much better developed in Germany than in England, which accounts for the use of the terms "Keuper" and "Bunter" for the upper and lower divisions even in this country. The occurrence of beds of rock-salt in the Trias of Cheshire, however, more than atones for the lack of palæontological interest possessed by the formation. These beds are supposed to have been formed by the evaporation of inland lakes communicating at intervals with the ocean, their great thickness (as much as 90 or 100 feet at Northwich in Cheshire) being accounted for by a slow subsidence of the land meanwhile.

Oolite, Lias, and Trias. **SECONDAR**

	British.		Foreign.	Character.
Upper.	Purbeck beds.	A belt nearly 30 miles in average breadth, stretching from Dorset in the S.W. to Yorkshire in the N.E., and passing through the Midland counties.	The Jura Mountains, France, Germany, North and South America, Asia, Australia.	Freshwater and estuarine san and marls.
	Portland Oolite.			Calcareous.
	Kimeridge clay.			Argillaceous.
Middle.	Coral rag.			Calcareous.
	Oxford clay.			Argillaceous.
Lower.	Cornbrash and			Calcareous.
	Forest marble, and Bradford clay.			Argillaceous.
	Great Oolite and Stonesfield slate.			Calcareous. Arenaceous.
	Fuller's earth.			Argillaceous.
	Inf. Oolite.			Calcareous.
Lias	Upper.	On the west side of the preceding.		Argillaceous.
	Middle, or Marl-stone.			Arenaceous.
	Lower.			Limestone and shale.

SECONDARY.

Fossils.		Thickness.	General Remarks.
Freshwater, like those of the Wealden beds, Paludina, Planorbis, Cyclas, also Cyrena, Crocodile, etc., and mammals.		150-200 ft.	Contains 25 species of mammals, which is more than all the other Secondary rocks together have yielded. The mottled freshwater limestone marbles so much used in churches are obtained from this formation.
O. expansa, A. giganteus.	Various species of Isastrea (coral), Cidaris, and Hemicidaris (echinoderms), Terebratula, Spirifera, and Rhynchonella (brachiopods), Ostrea, Gryphæa, Avicula, Modiola, Pholadomya, Trigonia, Cardium, and Lima (lamellibranchs), Pleurotomaria, Cerithium, Chemnitzia (gasteropods), Ammonites and Belemnites (cephalopods), with fishes.	100 ft.	The extensive development of Oolite and Lias in the Jura mountains has caused the word "Jurassic" to be applied to them. The regular succession of limestones and clays throughout the whole series gives rise to hills and valleys, as between London and Cheltenham, a feature which is reproduced in the country between Paris and Metz. Between each of the great limestone groups clays alternate, *e.g.* the Lias, Oxford, and Kimeridge clays. The industrial products of the system are building-stones, *e.g.* the Bath oolite, paving-stones, limestones, marbles, and lithographic slabs, alum shales, fuller's earth, and ironstone, especially in the Middle Lias of Yorkshire. At Brora in Sutherlandshire and in Yorkshire a coal-seam of middle Jurassic age has been worked. Hence, besides the abundance of animal life, there was an extensive flora which has not in the majority of cases been well preserved. Traces of volcanic action are absent. The formation of clays and limestones went on without any disturbance. The most conspicuous fossils are the huge saurian reptiles, many 20 ft. long, of which numbers have been obtained from Liassic strata at Lyme Regis in Dorsetshire. The oldest known fossil bird, Archæopteryx macrura, has been found in the lithographic slate of Solenhofen in Bavaria (Upper Oolite).
O. deltoidea, A. biplex.		500 ft.	
O. gregaria, A. perarmatus.		150 ft.	
O. undosa, A. jason.		400 ft.	
Pholadomya lirata.		20 ft.	
Ammonites discus.		50 ft.	
Apiocrinites Parkinsoni.			
Trigonia impressa.		100 ft.	
A. gracilis.			
Cetiosaurus, Teleosaurus, and mammals.			
O. acuminata.		80 ft.	
A. Humphresianus. Pholadomya fidicula. Pleurotomaria ornata.		200 ft.	
O. liassica, A. communis. A. bifrons, Gryphæa incurva. Lima gigantea, Avicula cygnipes, Ichthyosaurus, Plesiosaurus, Extracrinus.		800 ft.	

N.B.—The letter A is here used as a contraction for Ammonites, and O for Ostrea.

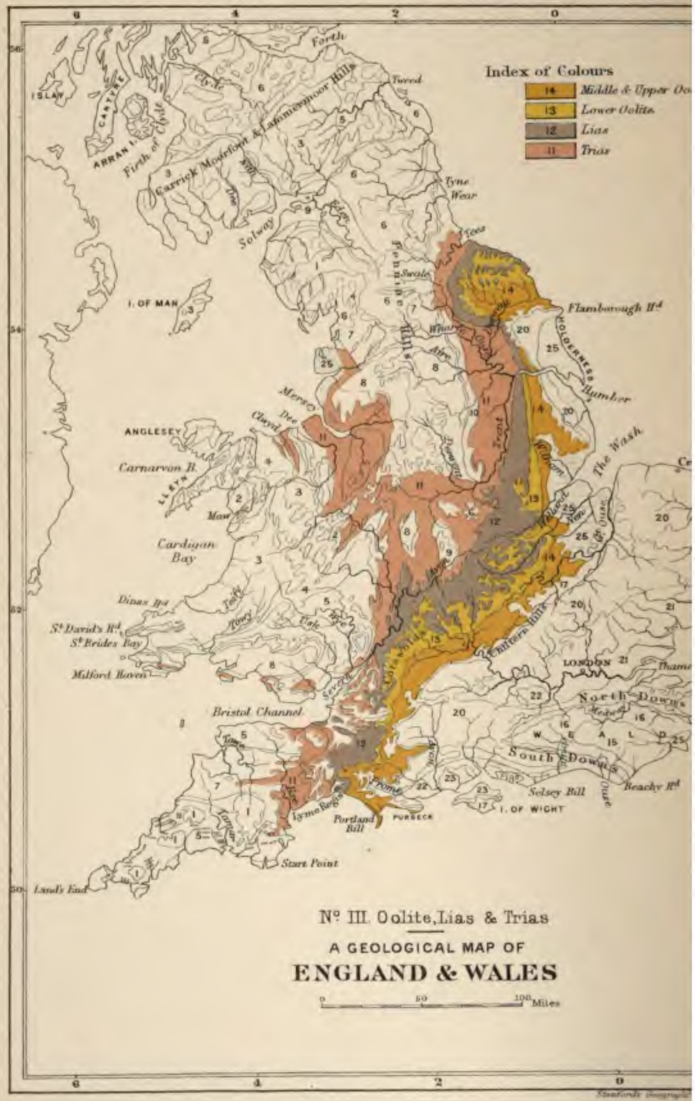
Oolite, Lias, and Trias—(*Continued*). SECONDA

	British.		Foreign.	Character.
Trias	Keuper.	In the N.E. and N.W., outside the Lancashire and Yorkshire coal-fields, the two branches meet in Warwick and Leicester, and continue to the south of England, South Devon and Dorset.	Germany.	Red clays, marls, shales, sandstones.
	Muschelkalk (wanting in England).			
	Bunter.			Sandstone and marl.

Summary.—The Oolite group was so called because, in the countries where it was
the word layers, and "Trias" refers to the triple division of that group in Germa
species of Ammonites found in the Lias, several have given their names to "zones" wh
these zones the Upper Lias contains three, the Middle three, and the Lower seven.
Lituite of the Palæozoic period. At Penarth, near Cardiff, in Glamorganshire,
occurs, containing Cardium Rhæticum and Avicula contorta, to which the name of Pena
other fossils are found in the more highly developed beds of the Rhætian Alps of Bava
Rhætic, Triassic, and Permian beds from the colour of the sandstones.

Fossils.		Thickness.	General Remarks.
Avicula contorta. Cardium rhæticum. Modiola minima. Monotis decussata.	Footprints and teeth of Labyrinthodon, various reptiles and fishes.	4000 ft. 100 ft. in England.	Also called New Red Sandstone, as being similar in mineral character to the Old Red Sandstone, but above the coal. "Keuper" means "copper," in allusion to its copper-bearing character in Germany; "Muschelkalk" means shelly limestone; and "Bunter" variegated. The system furnishes rock-salt in Cheshire in beds sometimes 80 or 100 ft. thick, and in places much gypsum. Although Triassic fossils are scarce in England, they are by no means wanting in the Muschelkalk of Germany, Ceratites nodosus and Encrinites liliiformis being the most important. The members of the series usually lie unconformably on older rocks.

examined, the limestones belonging to it had an oolitic structure. "Lias" is a corruption of
Cephalopoda were at their maximum in the Jurassic period, and of the enormous number of
can be traced into widely separated regions, as, for instance, England and the continent. Of
complex forms of the Nautilus and Ammonite are a decided advance on the Orthoceras and
other places on the borders of the Severn, a formation intermediate between the Lias and Trias
is given by the Government surveyors, but which is also called Rhætic, because these and
The term "Pòikilitic" (Gr. *poikilos*, variegated) was applied by Phillips to the group of



Nº III. Oolite, Lias & Trias

A GEOLOGICAL MAP OF

ENGLAND & WALES

world at large, inasmuch as it furnishes coal in the following countries—England, Scotland, Ireland, France, Spain, Belgium, Saxony, Prussia, Bohemia, Hungary, Sweden, Russia, Greece, Turkey, Persia, India, China, Australia, Tasmania, New Zealand, North America, South Brazil, Siberia, and Spitzbergen. The coal-seams are interstratified with sandstones, shales, and limestones of freshwater and marine origin, and are usually only a few feet thick, but are met with at many different levels in the same locality. The mass of the coal itself is made up of the remains of a former vegetation all but confined to flowerless plants, such as ferns, calamites, etc.

The oldest known reptile, Archegosaurus, occurs in the coal-field of Saarbruck near Trèves on the Moselle; it is one of the Labyrinthodonts, an extinct order of reptiles remarkable for the complex folds of the enamel of their teeth.

The Millstone Grit is composed of sandstones, shales, and conglomerates, containing very few fossils; the Carboniferous limestone, however, contains them in profusion, especially brachiopods and corals, and in addition about 240 species of fish are known, the majority of which have large flat teeth adapted for grinding and crushing the shells of mollusca.

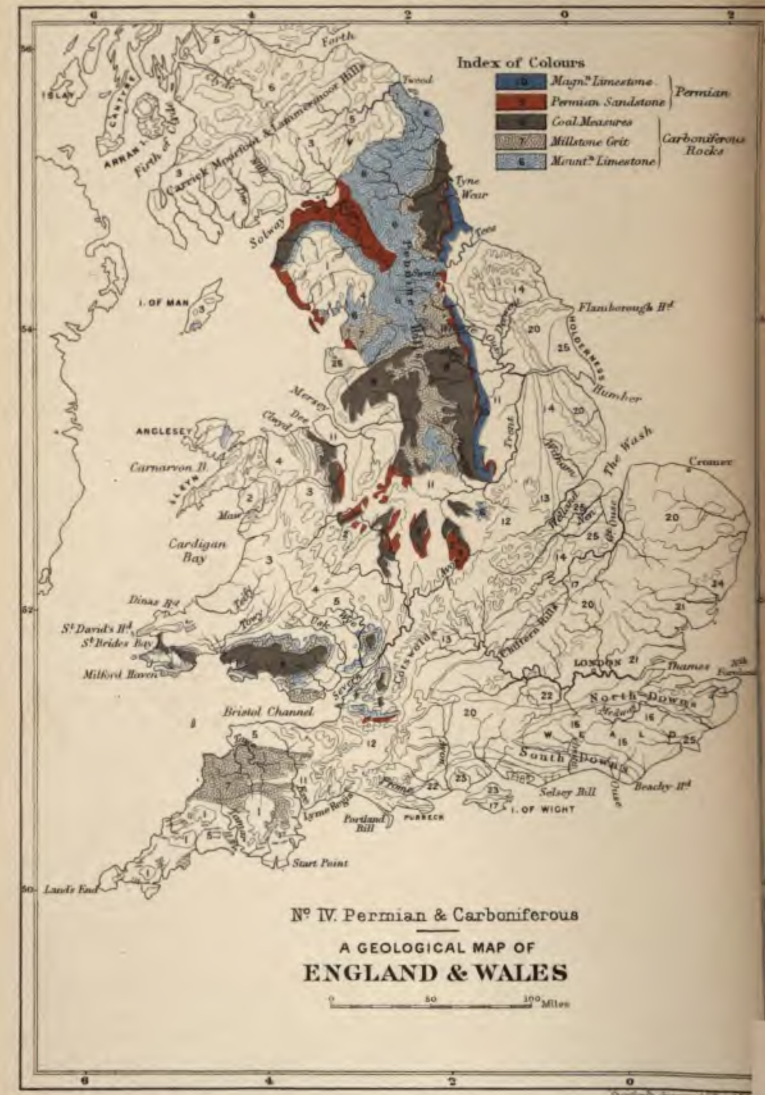
		British.		Foreign.	Character.
PERMIAN.		Upper Middle Lower	Cumberland, Durham, and Yorkshire.	Perm (Russia), France, Saxony, etc.	Red sandstones and clays in the west, Magnesian limestone in the east.
CARBONIFEROUS.	Upper.	Coal-measures.	From Northumberland, through the north central parts of England to between Staffordshire and Nottinghamshire; in South Wales and Devonshire.	Very extensive and widely distributed.	Numerous bands or seams of coal intermixed in particular localities with sandstones, shales, and limestones of mixed terrestrial, marine, and freshwater origin.
		Millstone Grit.			Coarse and fine sandstone and conglomerate, usually devoid of coal; hence called "Farewell Rock" in South Wales and the Bristol coal-fields.
	Lower.	Mountain or Carboniferous Limestone.			Largely made up of corals, shells, and encrinites.

Summary.—The coal-fields, wherever found, indicate a rank exuberance of vegetation such
all its water and various gaseous compounds, till the residue is chiefly carbon, with
ticular, namely fire-damp, which consists of carbon and hydrogen, is the cause of
90 per cent of carbon, is very hard, and kindles with difficulty, but burns without
and softens by heat; and cannel coal, a variety of the preceding, used for making gas.
used. Coal is not by any means solely a product of the Carboniferous age, but occurs
products of the system are building-stones and flagstones, fireclays, alums, pyritous

PRIMARY.

Fossils.	Thickness.	General Remarks.
Fenestella (a polyzoon). Productus horridus, Spirifera, Lingula. Abundant fish with heterocercal tails; footprints, and other traces of Labyrinthodon.	950 to 3600 ft.	Palæozoic forms, *e.g.* Spirifera and Productus, appear. Traces of ice-action, in the shape of transported blocks, have been observed, and it is not impossible that there may then have been a Glacial epoch. Magnesian limestone, when compact, is called "Dolomite"; it also occurs crystalline, brecciated, globular, or oolitic. Derives its name from the province of Perm, and yields coal in the other two countries mentioned, and in Silesia and Thuringia.
Freshwater and marine shells in some of the intercalated strata; of the first class are two or three referred to the family Unio, and of the second class (marine), Goniatites and Aviculo-pecten. An enormous number of Cryptogams, *e.g.* Ferns, Pecopteris, Sphenopteris, etc.; club-mosses, Lepidodendron; Sigillaria; Stigmaria; Calamites.	600 to 10,000 ft.	The coal-seams in the South Wales coal-field, though 80 in number, make up only 120 feet out of a total of 10,000. Each seam in a coal-field rests on a layer of clay known as the under-clay, often used for making fire-bricks, and containing roots of Sigillaria, which were called Stigmaria before their true nature was known. Bands of clay ironstone are numerous in the Coal-measures of some coal-fields. The climate was probably hot and moist.
Not abundant, but in the main coinciding with the above.	600 ft.	Occurs between the Lancashire and Yorkshire coal-fields, and has been laid bare by the denudation of the once-continuous Coal-measures. It is well seen in the Gloucestershire coal-field and round the Welsh coal-field.
Lithostrotion and Syringopora (corals), numerous encrinites; Spirifera, Productus, Euomphalus, Goniatites, Orthoceras, and many fishes.	Variable up to 2000 ft.	Forms a broad anticlinal curve in Derbyshire, where it is much used for building purposes, and for making quicklime.

as occurs in tropical countries. The woody fibre has in course of time parted with nearly
small quantity of mineral matter, the ash. The evolution of one of these compounds in par-
explosions in coal-mines. The chief varieties of coal are anthracite, which contains about
smoke or flame for a long time; caking or bituminous coal, which burns with much flame,
Coal-tar, which comes off during the distillation, is the source of the aniline dyes so extensively
in Secondary and even Tertiary formations in different parts of the world. The industrial
shales, and bituminous shales by the distillation of which paraffin and paraffin oils are obtained.



Nº IV. Permian & Carboniferous

A GEOLOGICAL MAP OF

ENGLAND & WALES

0 50 100 Miles

Stanford's Geograph^l Estab^t

CHAPTER X.

THE DEVONIAN, SILURIAN, CAMBRIAN, AND LAURENTIAN PERIODS.

THE red sandstones and shales which underlie the Carboniferous series present themselves in England under two different aspects, both as to their mineral character and fossil contents; the one (Old Red Sandstone) appearing to be of freshwater origin, the other (Devonian) of marine. The Old Red Sandstone is sometimes called the "Age of Fishes," from the prevalence of this class of vertebrates amongst the fossils. The majority of them are "ganoids," *i.e.* they have shining enamelled scales like the bony pike (Lepidosteus) of North American rivers.

Some more anomalous forms also existed, as, for instance, the Pterichthys, so called from two wing-like appendages, one on each side of the head, which doubtless corresponded with the foremost pair of fins of ordinary fishes. Another curious form was the Cephalaspis, a fish provided with an extraordinary head-shield, nearly 7 inches long (see Plate V.)

The Marine or Devonian group is best developed in North and South Devon; in the northern, although much contorted and folded, the rocks have not been altered by intrusive trap rocks and granite, as is the case in the southern parts of the county. They consist of slates, schists, sandstones, conglomerates, and calcareous bands, containing a considerable number of corals, crustacea, brachiopoda, and other molluscs, and plants; the latter (in the Upper Devonian) closely related to the Carboniferous flora.

The Silurian system attains an immense thickness in England and elsewhere, and is of the highest economic value and theoretical importance. It comprises slates, limestones, flags, sandstones, grits, conglomerates, etc., which, owing to their antiquity, have been much contorted, altered, and displaced by igneous and other subterranean forces, especially in South Wales. The number of fossils of the period is extremely large, and includes all the important classes of invertebrates, together with fishes; the latter, however, are not found beneath the Lower Ludlow (Upper Silurian); graptolites, corals, trilobites, and brachiopods are particularly numerous; the former are so called from their resemblance to a quill pen; those in which the cellules are developed on each side of the axis or stem are, with hardly an exception, confined to Lower Silurian rocks, while those having cellules on one side only range through both the Upper and Lower divisions.

The lowest rocks visible in North Wales and its borders are called the Cambrian rocks; they occur only in isolated patches, but attain a thickness of no less than 23,000 or 25,000 feet. The following are the principal localities where they occur—in the hilly ground between Harlech and Dolgelly in Merionethshire, on the west side of the peak of Snowdon, in Anglesea, at St. David's in Pembrokeshire, in a range of hills known as the Longmynd in Shropshire, in the Malvern range and the Lake district, as well as in Scotland and Ireland. The fossils are numerous, considering that the date of the period is estimated at more than 28,000,000 years ago,[1] and comprise trilobites, brachiopods, lamellibranchs, cephalopods, annelids, and traces of marine algæ.

Stratified rocks of pre-Cambrian age are met with at St. David's and North Wales, also in the Malvern Hills, but in the absence of fossils their age cannot be definitely fixed. The oldest fossil yet known is the Eozoon Canadense, a foraminifer found in an enormous mass of deposits called Laurentian occurring in Canada; in Britain the "fundamental gneiss" of Ross-shire, Sutherlandshire, and the Isle of Lewis is probably of contemporary age, though the Eozoon has not been discovered in it.

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[1] *Island Life*, p. 227 (1880). Some would make it very much more than this.

	British.	Foreign.	Character.
Fresh-water or Old Red Sandstone.	North of Scotland, and border between England and Wales.		Sandstones, chiefly red, but sometimes green, purple, or gray; shales, limestones, and conglomerates.
Marine or Devonian.	Upper or Pilton. Middle or Ilfracombe. Lower or Lynton.		Sandstones, limestones, and roofing slates.
SILURIAN. Upper.	Ludlow. Wenlock. Llandovery. Wales, Cumberland, and Westmoreland.	Russia, United States, and Canada.	Argillaceous strata, slaty and shaly, sandstones, limestones, grits, and conglomerates, with volcanic traps, ash and greenstone.
SILURIAN. Lower.	Bala and Caradoc. Llandilo. Arenig and Stiper stones group.	In almost all countries.	

Summary.—Trilobites very abundant, especially in the Silurian. They are Phyllopod
stones, limestones, and shales of the Lower, as well as in the Cambrian slates and flags;
group, is fairly rich, and comprises Calamites, Ferns, Lycopods, Sigillaroids, and Coni-

PRIMARY.

Fossils.	Thickness.	General Remarks.
Ganoid and Placoid fish, Eurypterites; no marine corals or shells; only one freshwater shell, Anodonta.		Two divisions recognised—the marine or Devonian, the freshwater or Old Red Sandstone; they are supposed to be of contemporary age. Volcanic action can be shown to have gone on by the interposition of greenstones. Metallic veins are met with in some cases. Thin seams of a Devonian coal occur in Canada, and also remains of the oldest known insect. The Devonian rocks occupy a large space in North and South Devon and Cornwall.
Spirifera, Atrypa, Orthis, corals, Trilobites, and Lamellibranchs.	Together with the preceding about 10,000 ft.	
Favosites, Halysites, Syringopora, Graptolites, Tentaculites, Atrypa, Orthis, Lingula, Spirifera, Rhynchonella, Pentamerus, Strophomena, Orthoceras, Lituites, Trilobites.	7400 ft. in all.	The Silurian period is sometimes called the "Age of Brachiopods," these forming about two-thirds of the whole bivalve fauna, whereas at the present day they form but a fraction of it. The name has been derived from the Silures, an ancient British tribe. The Ludlow bone-bed, which is only a few inches thick, has been traced 45 miles from Ludlow into Gloucestershire; it is made up of the bones, teeth, and scales of fish. Remains of vertebrates have not been observed in rocks older than the Lower Ludlow. There is much evidence of volcanic action in the Silurian rocks, and the system is rich in metallic veins, copper, lead, tin.
Rastrites, Graptolites, Dictyonema, Palæaster, Orthis, Strophomena, a few Lamellibranchs and Gasteropods, Orthoceras, and Trilobites.		
Worm-tracks, Trilobites, Graptolites.	26,000 ft. in all.	

Crustacea, and abound in the shales and limestones of the Upper Silurian, and in the sand-
no less than 300 species are known. The Devonian flora, considering the antiquity of the
fers, as in the Carboniferous.

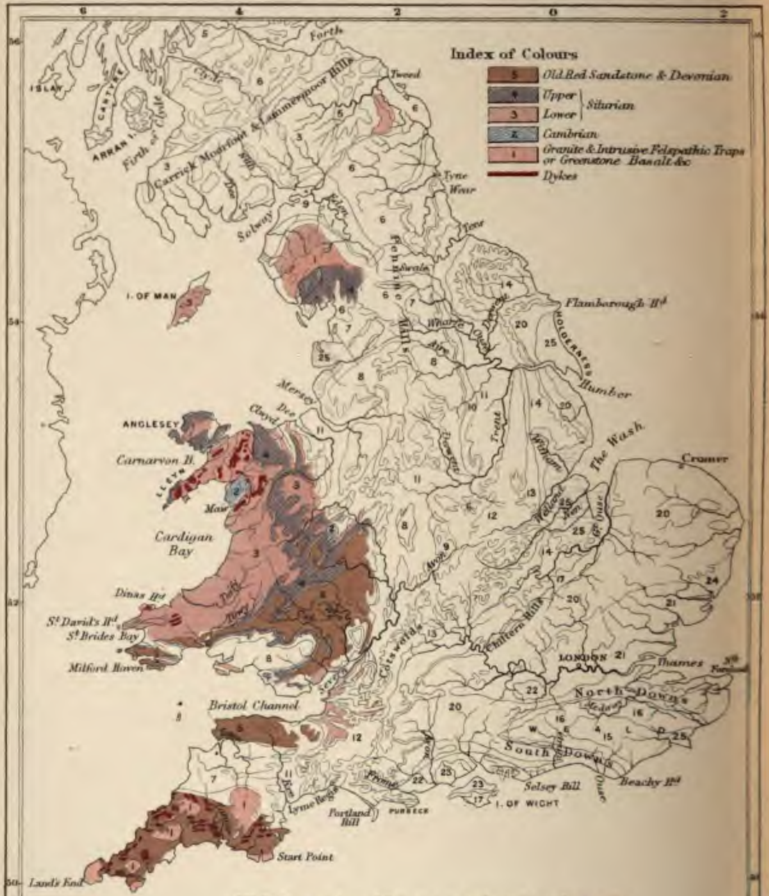
		British.		Foreign.	Character.
CAMBRIAN.	Upper.	Tremadoc slates. Lingula flags.	North and South Wales, Shropshire, Malvern.		Dark earthy slates. Micaceous flagstones.
	Lower.	Menevian beds. Longmynd group.			Dark gray and black flag and sandstones. Gray, green, purple, a grits, slates, and con ates.
LAUREN-TIAN.		Ross-shire, Sutherlandshire, Isle of Lewis.		Sweden, Norway, United States, and Canada. In Canada covers upwards of 200,000 square miles.	Crystalline gneiss with limestone and granite

Summary.—There is no part of the globe where such a varied succession of **strata** is p
from the Palæozoic rocks, the agricultural chiefly from the Secondary and **Tertia**

ARY.

Fossils.	Thickness.	General Remarks.
ites, Lingulella, Ortho- ; no Gasteropods, very Lamellibranchs. mia radiata and O. ua, Trilobites, Lingu- , Worm-tracks.	23,000 or 25,000 ft.	The name "Cambrian" is derived from *Cambria*, Latin for Wales. Menevia is the classic name for St. David's. The Longmynd is a low ridge of hills to the north-west of Church Stretton in Shropshire. Industrial products, roofing slates, marbles, flags, ores of iron, tin, copper, and lead. Oldhamia may be a plant (Calcyphite), though it is referred to the Hydrozoa.
		Supposed to correspond in date with the Laurentian rocks of North America, because Cambrian and Metamorphic Silurian rocks rest unconformably on them. The Eozoon Canadense has not been discovered in Great Britain.
n Canadense.	More than 30,000 ft.	Furnishes serpentines, marbles, quartzites, graphite, and ores of iron. Takes its name from the St. Lawrence River. The Eozoon consists of alternate layers of organic or eozoonal limestone and serpentine; it is supposed to be a foraminifer, and occurs in one of the limestones of the series.

the same area, as in Great Britain. The mineral wealth of the country is derived



Nº V. Devonian, Silurian, Cambrian & Igneous

A GEOLOGICAL MAP OF

ENGLAND & WALES

0 50 100 Miles

Stanford's Geograph¹ Estab¹ London

CHAPTER XI.

IGNEOUS ROCKS.

THE chemical constituents of igneous rocks are practically limited to seven in number, namely Silica, Alumina, Magnesia, Oxide of Iron, Lime, Potash, and Soda; of which the first is invariably present in considerable quantity, and is called the acidic constituent, as being the oxide of a metalloid; the rest, and especially the three last, are called basic, being the oxides of metals. Igneous rocks are mechanical mixtures of minerals, and are partly classified in reference to their origin, partly in reference to the predominating or distinguishing mineral they contain. The following are the chief rock-forming minerals arranged in groups:—(1) the Quartz group, comprising only Quartz and Tridymite, which consist entirely of silica; (2) the Felspars, of which silicate of alumina is the representative ingredient; (3) the Amphibole and Pyroxene group, containing silicate of magnesia; and (4) the Mica group, intermediate between the second and third, and less important than either.

The Felspars are divided, according to their chemical composition, into (1) Orthoclase, common or potash felspar; (2) Albite, or soda felspar; (3) Oligoclase, or soda-lime felspar; (4) Labradorite, or lime-soda felspar; and (5) Anorthite, or lime felspar. They consist of a mixture of silicates of alumina and one or more of the three bases, potash, soda, and lime; but when the first, for instance, is called potash felspar it is not meant to imply that potash is the only base present, but that the proportion of the others is insignificant.

Orthoclase is so called because the angles between its cleavage faces are right angles; the remainder are Plagioclase, because in them the fractures are oblique (though very slightly). The first three are most common in acidic rocks, the remainder in basic.

The Amphibole and Pyroxene group, of which Hornblende and Augite respectively are the representatives, are united in one as containing a large proportion of silicate of magnesia, but differ in that the former contains less lime but more iron than the latter. The Amphibole group includes Hornblende, Actinolite, Tremolite, and others; the Pyroxene group, Augite, Diallage, Hypersthene, Bronzite, Diopside, etc. The Mica group includes (with other less common varieties) Muscovite, common or potash mica; Lepidolite, lithia mica; Margarodite, black mica; and Lepidomelane, white mica; with talc, chlorite, and steatite.

Igneous rocks are divided into Volcanic or Trappean, and Granitic or Plutonic, according as they have cooled at or near the surface, under little or no pressure, or slowly at great depths under considerable pressure. The Volcanic rocks are divided into two groups, according to the proportions of acid (*i.e.* silica) and base which they contain. Those which contain

60-70 per cent of silica are termed acidic, felspathic, or trachytic; and those which contain less than 55 per cent of silica are termed basic or basaltic. A tabular list is subjoined :—

Volcanic Rocks.

Felspathic, Trachytic, or Acidic.	*Basic, or Basaltic.*	
Trachyte, Pearlstone.	Dolerite, Basalt, Wacke.	Augitic.
Clinkstone or Phonolite.		
Obsidian, Pumice.	Diallage rock, Diorite, Hypersthene rock, Diabase.	Hornblendic.
Felstone, Porphyrite.		

Volcanic tuffs and breccias are called Fragmental, and may belong to any of the above divisions.

Amygdaloids and Porphyries (see Glossary) are simply rocks presenting a special form of structure, with no restriction as to their composition.

Plutonic rocks are described by Lyell as the unstratified division of the crystalline formations which differ from the preceding, not only by their more crystalline texture, but also by the absence of tuffs and breccias, and of pores and cellular cavities. They are never bedded, but always intrusive, and contain abundant water-cavities. The typical Plutonic rocks are **granite** and **syenite**: the former is composed of quartz, felspar (usually orthoclase), and mica, each distinguishable in the mass; the acidic constituent silica making up about 72 per cent of the whole weight. The most important varieties of **granite** are Protogine; Syenitic or Hornblendic granite; Pegmatite, in which the crystals of felspar are often very large; and graphic granite, so called because the quartz is crystallized in such a manner as to produce on

INVERTEBRATA.

Foraminifera.	Sponges.	Cœlenterata	Echinodermata	Crustacea and Insecta.	
Body composed of structureless albuminoid substance, sometimes protected by a perforated shell (whence the name), sometimes by an imperforate one. Ex. Nummulites, Eozoon, Fusulina, Globigerina.	Soft albuminoid substance enclosing siliceous or calcareous spicules; have two sets of holes, one smaller for sucking in currents of water, the other larger for expelling it. Ex. Ventriculites, Siphonia, both cretaceous.	Consist of two fundamental layers surrounding a digestive cavity. The most important examples are corals and graptolites. Ordinary coral is the internal calcareous skeleton of a colony of polypes, each like a sea-anemone. The following are some of the chief fossil corals: Astræa, Isastræa, Thecosmilia, Halysites or chain-coral, Heliolites, Lithostrotion, Cyathophyllum. Graptolites are composed of overlapping cellules attached to an axis, sometimes on one side, sometimes on both. In Rastrites the cellules do not overlap.	Have an alimentary canal completely shut off from the rest of the body, and a distinct nervous system. The following are the chief orders:— (1) *Echinoidea.* Ex. Ananchytes, Galerites, Micraster, Spatangus, Cidaris, and Hemicidaris. These carried spines which are numerous as fossils. (2) *Asteroidea* or Star-fishes, of which the Lower Silurian Palæaster is an example. (3) *Crinoidea*, including Encrinites, Pentacrinites, Actinocrinus, Marsupites, etc., some of which are called sea-lilies.	Body composed of a series of segments, with jointed limbs on all or nearly all of them. *Crustacea* are provided with gills, and their mode of existence is more or less aquatic. Have an external crust or shell which in crabs and lobsters, amongst others, is renewed from time to time. Ex. Barnacles, Cyprides, Trilobites, Eurypterites, Cray-fish, Limulus or King-crab, ordinary crabs, and lobsters. Trilobites are exclusively Palæozoic, Eurypterites chiefly Old Red Sandstone; the body of the former was divided longitudinally into three lobes and transversely into a number of segments varying from 2 to 26.	In *Insects* the head, thorax, and abdomen are distinct; the thorax consists of three segments, each of which carries a pair of legs. Amber, a Post-tertiary resin, has furnished a large number, and the Upper Miocene beds of Oeningen contain them in profusion, otherwise they are not numerous as fossils. The oldest is from the Devonian of Canada. Many genera occur in the Purbeck rocks and Upper Tertiaries.

INVERTEBRATA.

Polyzoa.	**Mollusca or Shell-fish.**			
Animals forming moss-like or coral-like calcareous or horny masses of cells, each containing a worm-like creature without a heart and with a single or double nervous ganglion near the mouth. Exs. Flustra or sea-mat, Dictyonema, Fenestella, Fascicularia. From their organisation the Polyzoa and Brachiopoda are often called Molluscoida and separated from the shell-fish bearing Mollusca proper.	Soft-bodied; protected by a univalve or bivalve shell composed mainly of carbonate of lime; very valuable as fossils. Valves secreted by a "mantle," which leaves scars or lines on their inner surface; these lines often serve to distinguish different genera of Lamellibranchs.			
		Those having three principal pairs of ganglia and a well-developed heart.		
	Brachiopoda.	*Lamellibranchiata.*	*Gasteropoda.*	*Cephalopoda.*
	Animal with one pair of nervous ganglia, heart imperfect; no eyes, no circulatory system. Has two spirally coiled arms capable of reaching beyond the edge of the shell; the mouth is between them. Shell composed of two unequal symmetrical valves. Exs. Terebratula, Lingula, and Rhynconella, which still survive; the following, amongst others, are extinct: Pentamerus, Productus, Spirifera, Strophomena, Atrypa, Orthis, etc. The shells of Terebratula are called Lamp-shells, from their resemblance to an ancient lamp.	Head not distinct, mouth unarmed. Valves usually, but by no means always, equal and unsymmetrical, closed by powerful adductor muscles which leave impressions inside, sometimes single, sometimes double. They anchor themselves to a rock, or burrow in sand or mud. Saxicava and Pholas bore holes in rocks, Teredo or ship-worm in wooden piles or the bottoms of ships. Exs. Ostrea or oyster, Mytilus or mussel, Cardium or cockle, Trigonia, Lima, Arca or ark, Pecten or scallop, Tellina, Gryphæa, Astarte, Chama, Nucula, Cardita, Crassatella, Solen or razor-fish, Diceras, Avicula, Hippurites.	Distinct head, with eyes and ears, mouth armed with a lingual ribbon instead of teeth. Can move about by means of a ventral disc or foot, whence the name. Univalve shell, not chambered (except Euomphalus, and it has no siphuncle), coiled so as to be conical, discoidal, or convolute (as in the cowries). Those in which the margin or lip of the shell is complete are mostly vegetable feeders; those in which it is notched are carnivorous. The simplest form is the limpet. Exs. Buccinum or Whelk, Conus (cone), Mitra (mitre), Oliva (olive), Voluta (volute), Cerithium, Turritella, Littorina (periwinkle), Turbo (top-shell), Trophon, Planorbis, Dentalium, Limnæa, Terebellum, Pyrula, Murex, Cypræa (cowry).	Have eight or more arms used for locomotion or for seizing their prey, disposed in a circle round the mouth, which is armed with teeth like a parrot's beak. Eyes highly organised, brain enclosed in a cartilaginous sac, foreshadowing the skull of vertebrates: univalve chambered shell, shape very various. Some however, have no shell at all. Exs. Octopus, Cuttle-fish, Nautilus, Ammonite, Orthoceras, Hamite, Baculite, Scaphite, Turrilite, Belemnite. The shells of Nautili and Ammonites are best distinguished by the sutures, which in the former are simple, in the latter very complex; and by the siphuncle, which in the former is medial, in the latter circumferential or ventral.

VERTEBRATA.

Animals whose spinal cord is protected by a bony axis, the

Fishes.	Amphibians	Reptiles.	Birds.
Blood cold; animal provided with gills which perform the function of lungs; limbs in the form of fins, the paired fins are homologous with the fore and hind limbs of higher vertebrates; the unpaired ones are merely appendages of the skin, and are not connected with the spinal column. Fishes possess teeth on the tongue and palate, as well as in the jaws, but they are never sunk in sockets. The older types had heterocercal tails (see Glossary); modern ones, with very few exceptions, have homocercal ones. Some, however, when very young, have heterocercal tails, which afterwards change. Very abundant as fossils; the oldest are from the Lower Ludlow beds (Upper Silurian). Many also occur in Old Red Sandstone, Permian, Cretaceous, and Eocene. The terms ganoid and placoid are explained in the Glossary.	Include Frogs, Toads, Salamanders, and Labyrinthodonts. True lungs present in the adult; the young have gills, but lose them in the metamorphosis, *e.g.* from tadpole to frog, which they all undergo. Labyrinthodon, so called from the complex structure of its tooth, is conjectured to be the same as the Cheirotherium, whose footprints are found in the Trias. Occurs also in Permian and Carboniferous.	Blood cold, body often protected by an armour of some kind. Comprise tortoises and turtles, snakes, lizards, crocodiles, and several extinct forms from the Jurassic and Cretaceous. Tortoises and Turtles are enclosed in a bony case or box into which the former can retract its head, but the latter cannot. They have no teeth, but horny beaks instead. Snakes have an elongated, cylindrical body in which the paired organs, such as the lungs, are placed, not side by side, but one behind the other; the limbs are altogether wanting. An Eocene sea-serpent is known, called Palæophis typhæus. Crocodiles form the highest division of living reptiles; their lacertian shapes are familiar. The Gavial or Gangetic crocodile has an elongated snout somewhat like a sword-fish. Ichthyosaurus had a very short neck, enormous eyes, and paddles for swimming. Plesiosaurus differed from it chiefly in having a small head but a very long neck. The two words mean respectively fish-lizard, and like or allied to a lizard. Pterodactyl or wing-fingered reptile had four digits on the hand, the outermost of which was enormously lengthened to allow of a membrane being stretched between it and the leg of the same side. No known reptile can fly. The Iguanodon of the Jurassic and Cretaceous was very like the modern Iguana, but was about ten times as long, 50-60 feet.	Blood warm, body covered with feathers; fore-limbs modified so as to constitute wings. The lungs of birds communicate freely with the interior of the bones, to give lightness to the body. Occur fossil chiefly in the Cretaceous and Tertiary; the oldest is the Archæopteryx from the Upper Oolite of Solenhofen in Bavaria. This and several of the other extinct birds had teeth, which are not possessed by any modern ones. The Dodo of Mauritius, the Moa and Dinornis of New Zealand, and the Solitaire of Rodriguez have become extinct in historic times.

VERTEBRATA.

vertebral column. Limbs never more than four in number.

Mammals.

Blood warm, young brought forth alive; lungs always protected by ribs. Normal number of digits is five, both for the fore and hind limbs, except where they are reduced for special purposes; thus the horse has only one, which can be proved to be homologous with the middle finger, the longest and strongest of the human hand. Fossil Mammals are entirely Tertiary, except for the Marsupials of the Purbeck, Stonesfield slate, and Trias.

II. *Marsupialia.*	VI. *Ungulata.*	XI. *Proboscidea.*	XII. *Carnivora.*	XVI. *Quadrumana.*
The lowest mammals with one exception, the Monotremata. The young are brought forth alive, and so far are an advance on the eggs of birds and reptiles, but they are so weak that they have to be carried about in a pouch for a time. They are confined to Australia and the American continent. Four species are known from the Trias of Somersetshire, Wurtemburg, and N. Carolina, twenty-five from the Middle Purbeck of Dorsetshire, and four from the Oolite of Stonesfield near Oxford. **Order III.—The Edentata comprise Sloths, Armadillos, Ant-eaters, and the extinct Megatherium. The latter was a vegetable feeder, and made a tripod of its hind-legs and tail, while with its fore-legs it conveyed branches of trees, etc., to its mouth.** *Cetacea,* **comprising Whales, Dolphins, and Porpoises; and** *Sirenia,* **comprising Dugongs and Manatees, form Orders IV. and V. The hind limbs are wanting, and the tail is horizontal in both.**	The Hoofed Quadrupeds; divided into odd-toed, viz. Horse, Tapir, and Rhinoceros; and even-toed, viz. Hippopotamus and Pig, which do not ruminate, and Oxen, Sheep, Goats, Camels, Llamas, Antelopes, and Giraffes, which do ruminate. They are known fossil from Pliocene to Recent; one of the most important British fossil Ungulates is the great Irish elk (Pleistocene). See p. 34.	Have a trunk or proboscis instead of a long neck; the incisor teeth are enormously developed and are called tusks, of which modern Elephants, whether African or Asiatic, have two only, and those in the upper jaw; the Mammoth, and occasionally the Mastodon, had two in each jaw, and the Dinotherium two in the lower jaw only, which were curved downwards.	The Cat family (Cat, Lion, Tiger, Leopard, Lynx) and the Dog family (Dog, Fox, Wolf, Jackal) are distinguished by their habit of walking on the tips of the toes. Bears and Badgers use the sole of the foot for that purpose. In Seals and Walruses the feet are placed very far back and are modified into paddles. Order XIV.—The Cheiroptera include Bats, which can truly fly, but their bones are not hollow like those of birds.	Apes, Monkeys, Baboons, and Lemurs. The hind limbs are provided with a true prehensile hand. Appear first in the Eocene of N. America. Order XVII. contains but one genus and one species, the Homo sapiens of Linnæus. The anatomical differences amongst men are not great enough to be called specific; they merely separate the different races.

The Roman numerals in the above table are the numbers of the different Orders, of which there are seventeen altogether; the omissions are either those of living orders unimportant from a palæontological point of view, or extinct ones made for the reception of one or two genera.

VEGETABLE KINGDOM.

Plants are divided in the first place into two groups—the Phanerogams and the Cryptogams; the former of which have distinct flowers and seeds, the latter have neither true flowers nor fruit. The following remarks contain nearly all that a book of this nature requires:—

<table>
<tr><th>CRYPTOGAMS</th><th colspan="2">PHANEROGAMS</th></tr>
<tr><td rowspan="3">Comprise sea-weeds, lichens, fungi, liverworts, mosses, ferns, horsetails. Almost all Palæozoic plants are cryptogams, as is easily intelligible on the theory of progressive development. There was, however, no lack of large trees in the Carboniferous period.</td><td colspan="2">Are nearly all Tertiary or modern, and are divided into</td></tr>
<tr><td>Endogens</td><td>and Exogens.</td></tr>
<tr><td>Growth takes place from within; they have no bark, and exhibit no rings when cut across. In all the seed-lobe is single; hence they are sometimes called Monocotyledons. Grasses, lilies, and palms belong to this class.</td><td>Are secreted by the bark, and show rings of growth in a transverse section. The seed-lobe is always double, as in a bean or walnut, whence the name Dicotyledons. Most ordinary trees and shrubs are Exogens.</td></tr>
</table>

The Cambrian and Silurian plant remains are those of sea-weeds only; the Devonian formations indicate an abundant land flora, with ferns and conifers. The Carboniferous and Permian vegetations are much alike, and contain only a very few flowering plants. No Lepidodendra or Sigillaroids occur in the Trias; the representative Mesozoic vegetation is exhibited by the Jurassic and Lower Cretaceous groups. In the Upper Cretaceous of Aix-la-Chapelle and North America plants allied to modern genera begin to make their appearance. The European Tertiary plants up to Pliocene are remarkably American in character.

GLOSSARY.

The termination -ites or -lites is from the Greek *lithos*, a stone. The words marked with an asterisk are specific names; it is customary to put them in the feminine gender when so employed.

Actinocrinus (Gr. *aktis*, a ray; *krinon*, a lily). A genus of Palæozoic Echinodermata, abundant in the Carboniferous limestone.

Acuminatus* (Lat.), provided with a point.

Albogalerus* (Lat. *albus*, white; and *galerum*, a cap or hood).

Alluvium (Lat. *alluo*, to wash). The earthy deposit made by lakes or running streams, especially in times of flood.

Alumina. The oxide of the metal aluminium, known under the following forms—corundum, emery, sapphire, ruby, topaz.

Ammonites. A genus of Cephalopods, characteristically Mesozoic, so called from the resemblance of the shell to the horns of Jupiter Ammon, worshipped in Libya in the form of a ram.

Amphilestes (Gr. *amphi*, implying doubt; and *lēistēs*, a robber). One of the four genera of mammals obtained from the Stonesfield slate.

Amygdaloid (Gr. *amugdalon*, an almond; and *eidos*, form). A rock in which round or almond-shaped nodules of some mineral are enclosed in a base of compact rock. See also PORPHYRY. Both amygdaloids and porphyries admit of every variety of composition.

Ananchytes (Gr. *anagchitis*, a precious stone). A genus of Cretaceous Echinodermata.

Angiosperms (Gr. *aggeion*, a vessel; *sperma*, seed). Plants which have their seeds enclosed in a seed-vessel. Except pines and cycads, most ordinary trees and shrubs are angiosperms. See also GYMNOSPERM.

Annulatus* (Lat.), provided with rings.

Anodonta (Gr. "*a*," without; *odous*, *odontos*, a tooth). A fresh-water Lamellibranch found in Old Red Sandstone and Tertiary strata.

Anticline or **anticlinal curve** (Gr. *anti*, on opposite sides; *klino*, to bend). The convex curve of a bed or set of beds, produced by lateral pressure or upheaval from below. See also SYNCLINAL CURVE.

Apiocrinus (Gr. *apion*, a pear; *krinon*, a lily). A genus of Echinodermata common in the Oolites.

Aporrhais (Gr. *aporrheō*, to flow away). The spout-shell. A genus of Gasteropoda found in Tertiary strata. Four species are still in existence.

Arca (Lat. an ark). A Lamellibranch ranging from Lower Silurian to Recent periods.

Archæopteryx (Gr. *archaios*, ancient; *pteron*, a winged creature). The oldest known bird, from the Upper Oolite of Solenhofen in Bavaria. See p. 58.

Archegosaurus (Gr. *archaios*, ancient; *saura*, a lizard). The oldest known reptile, one of the Labyrinthodontia, obtained from the Coal-measures of Saarbrück.

Asaphus (so called from St. Asaph in Denbighshire). The characteristic genus of the family of Trilobites called Asaphidæ, obtained from Lower and Upper Silurian strata.

Astarte (the Phœnician Venus). A Lamellibranch, ranging from the Carboniferous period onwards.

Asteroidea (Gr. *astēr*, a star; *eidos*, form). See under ECHINODERMATA, table of Invertebrates, p. 86.

Atrypa (Gr. "*a*," not; *trupa*, a hole). A genus of Brachiopoda common in the Silurian period, so called because the beak was erroneously thought not to be perforated.

Aurantium* (Lat.), an orange.

Avicula (Lat. a little bird). The Aviculidæ range from Lower Silurian to Recent, and have eared shells, of which the posterior is winglike.

Baculites (Lat. *baculum*, a walking-stick). A Cephalopod ranging from Neocomian to Upper Cretaceous.

Belemnites (Gr. *belemnon*, a dart). A genus of Cephalopods, very abundant in the Jurassic and Cretaceous periods.

Bifrons* (Lat. *bis*, twice; *frons*, a front). Having a double front.

Bombs. Portions of lava which have been projected into the air, and have taken a more or less spherical or spindle-shaped form from rapid rotation.

Boulders. Masses of rock of any size or description which have been polished, scratched, or striated by being forced along the bed of a glacier.

Brachiopoda (Gr. *brachus*, an arm; *pous, podos*, a foot). In allusion to two appendages near the creature's mouth. See p. 87.

Breccia. A mass of small angular stones bound together by a cement. See also CONGLOMERATE.

Bronteus (from Brontes, one of Vulcan's workmen, a Cyclops). A genus of Trilobites from the Silurian and Devonian formations.

Buccinum (Lat. a trumpet, a triton's shell). Commonly known as whelks; they first appear in the Oolite, are also known in the Cretaceous and Eocene, and attain a maximum at the present day.

Cæspitosus* (Lat. *cæspes*, a hut or shed). Of a conical shape.

Cainozoic (Gr. *kainos*, new; *zoē*, life). Synonymous with Tertiary.

Calamites (Lat. *calamus*, a reed). Plants with reedlike stems, abundant in the Coal-measures.

Calcarius* (Lat. *calx*, chalk). Belonging to the Chalk.

Calymene. An island in the Ægean Sea. A genus of Trilobites of the Silurian period.

Canaliculatus* (Lat.), channelled.

Cannæformis* (Lat.), shaped like a reed or cane.

Carbon (Lat. *carbo*, coal). An element known under the three forms of diamond, graphite, and charcoal, the second of which occurs abundantly at Borrowdale in Cumberland, and in North America; like coal, it is doubtless of vegetable origin.

Cardita. Dim. of Cardium.

Cardium (Lat. a heart). The common cockle. The family are known as fossils from the Silurian period onwards, except in the Permian, Trias, Purbeck, and Wealden.

Carinata* (Lat.), keeled.

Carinifera* (Lat. *carina*, a keel; and *fero*, to carry).

Carnea* (Lat. *caro*, *carnis*, flesh).

Catenularinus* } (Lat. *catena*, a chain). Chainlike.
Catenulatus* }

Caudatus* (Lat. *cauda*, a tail). Provided with a tail.

Cephalaspis (Gr. *kephalē*, a head; *aspis*, a shield). A genus of fishes from the Devonian period, so called because provided with a head-shield.

Cephalopoda (Gr. *kephalē*, a head; *pous*, a foot). In allusion to the arms which spring from a circle round the mouth.

Ceratites (Gr. *keras*, a horn; and *lithos*). A genus of Cephalopoda from the Muschelkalk.

Cerithium (Gr. *keration*, a little horn). A genus of Gasteropods numerous in Tertiary strata.

Cetiosaurus (Lat. *cetus*, a whale; Gr. *saura*, a lizard). A gigantic reptile obtained from Stonesfield.

Chama (Lat. a cockle). A genus of Lamellibranchs, ranging from the period of the Greensand to the present.

Cheirotherium (Gr. *cheir*, a hand; *thēr*, a beast). A Triassic amphibian, conjectured to be the same as the Labyrinthodon, so called because its footprints resemble impressions made by a human hand.

Chelonia (Gr. *chelōnē*, a tortoise). An order of reptiles which includes turtles and tortoises.

Cidaris (Lat. a diadem or tiara). The Cidaridæ form an important family of Echinodermata belonging to the Jurassic, Cretaceous, and Tertiary periods.

Clausus* (Lat.), shut.

Cleavage. A tendency in certain rocks to split into plates in some direction or other, which may or may not be the same as that of the stratification, if any.

Cœlenterata (Gr. *koilos*, hollow; *enteron*, entrails). A sub-kingdom of Invertebrates which includes jelly-fishes, sea-blubbers, graptolites, sea-anemones, corals, and the remainder of the classes Hydrozoa and Actinozoa. See p. 86.

Comptus* (Lat.), adorned.

Conchifera (Lat. *concha*, a shell; and *fero*, to carry). Used as a synonym of Lamellibranchiata.

Conglomerate. A mass of small rounded or water-worn pebbles bound together by a cement.

Conifers (Lat. *conus*, a cone; and *fero*, to carry). A family of trees which bear cones, like the fir, larch, and pine; they are found so far back as the Upper Silurian.

Contrarius* (Lat. contrary, reversed). When applied to a shell it implies that it is coiled in the opposite way to the usual one,—in other words, that when either end is pointed towards one's body, the direction of the coil is from right to left upwards. *Fusus contrarius*, the reversed whelk of the Pliocene, is one of the commonest of reversed shells; similar examples are sometimes met with among garden-snails, whelks, and other genera.

Coprolites (Gr. *kopros*, dung; and *lithos*).

Cor-anguinum* (Lat.), a serpent's heart.

Corbula (Lat. a little basket). Lamellibranch. Inf.-Oolite-Recent.

Cordatus* (Lat.), wise, sagacious.

Costatus* (Lat.), ribbed.

Crannoges. Pile-dwellings of the Bronze and Stone Ages, found in many Irish and some English peat-bogs.

Crassatella (Lat. *crassus*, thick). Lamellibranch, common in the Barton clay (Eocene), but its full range is Neocomian to Recent.

Crenatus* (Lat.), provided with convex teeth.

Cretaceous (Lat. *creta*, chalk). Composed of or like chalk.

Crinoidea (Gr. *krinon*, a lily; *eidos*, form). See under ECHINODERMATA, table of Invertebrates, p. 86.

Crustacea (Lat. *crusta*, a crust). A class of Invertebrates which includes lobsters, crabs, barnacles, king-crabs, eurypterites, and trilobites, as well as many other families.

Cryptogams (Gr. *kruptos*, hidden; *gamos*, marriage). Plants having no true flowers or fruit.

Culm or **Culm measures**, a term applied to the carbonaceous rocks of Devonshire, on account of the workings for "Culm" or impure coals, near Bideford, etc.; they belong to the lowest or anthracitiferous series of South Wales.

Cyathophyllum (Gr. *kuathos*, a cup or bowl; *phūllon*, a leaf). A genus of corals from the Silurian and Devonian formations.

Cyclas (Lat.), orbicular. See CYRENA.

Cygnipes* (Lat. *cygnus*, a swan; *pes*, a foot).

Cyrena (the name of a nymph). Cyclas and Cyrena are two allied genera of Lamellibranchs, chiefly Tertiary; the shell of the former is thin, of the latter thick.

Decussatus* (Lat.), divided crosswise.

Deinotherium, or **Dinotherium** (Gr. *deinos*, terrible; *thēr*, a beast). A creature found in Miocene and Pliocene strata in Germany, France, and Switzerland, in which were mingled the characteristics of the elephant, tapir, hippopotamus, and dugong.

Deletus* (Lat.), blotted out, extinct.

Deltoidea* (Gr. the letter delta, Δ; and *eidos*, form). Like a delta or triangle.

Dentalium (Lat. *dens*, a tooth). A Gasteropod of which the shell is curved like a tooth; known from Devonian to Recent.

Denudation (Lat. *denudo*, to lay bare). The wearing away of rocks either by wind, ice, rain, rivers, or the sea.

Detritus (Lat. *de*, down; *tero, trīvī, trītum*, to grind). The term applied to earth, sand, silt, gravel, or alluvium, because the material is derived to a great extent from the wear of rocks.

Diceras (Gr. *dis*, double; *keras*, a horn). A somewhat aberrant Lamellibranch from Lower Cretaceous strata.

Dicotyledon (Gr. *dis*, double; and *kotulēdōn*, a cuplike hollow). Plants whose seeds can be split into two, like the walnut or bean. All Dicotyledons are Exogens, see p. 90.

Dip. This word, applied to a bed of rock, indicates that instead of being horizontal it is inclined towards some point or other of the compass, and the amount of inclination is called the "angle of dip."

Dolichodeirus* (Gr. *dolichos*, long; *deirē*, neck).

Dolomite. A limestone containing carbonates of lime and magnesia; so called from Dolomieu, a French geologist.

Dyke. A sheet of igneous rock which has forced its way into a pre-existing rock, or which has been injected into a fissure. From the fact that its sides are often nearly parallel and vertical, a dyke looks somewhat like a wall.

Echinodermata (Gr. *echinos*, a hedgehog, a sea-urchin; and *derma*, skin). A class of Invertebrates which includes sea-urchins, star-fishes, stone-lilies, etc.

Echinoidea (Gr. *echinos*, a sea-urchin; *eidos*, form). See under ECHINODERMATA, table of Invertebrates, p. 86.

Encrinites (Lat. *encrinus*, a lily). The Crinoidea form an order of Echinodermata. E. liliiformis is characteristic of the Muschelkalk.

Endogens (Gr. *endon*, within ; *gennao*, to produce). Plants which have no bark, and therefore exhibit no rings of growth.

Eocene (Gr. *ēōs*, dawn ; *kainos*, recent). The dawn of recent life. A subdivision of the Tertiary period, so called because it is the first which furnishes shells belonging to living species of mollusca.

Eozoon (Gr. *ēōs*, dawn ; *zōon*, an animal). The earliest fossil. See p. 86.

Erinaceus* (Lat. a hedgehog). Provided with spines.

Erratics (Lat. *erro*, to wander). Boulders of sufficient size to retain their position and character after having been deposited. If left in a singular or precarious situation on the top or side of a hill they are called "perched blocks."

Escarpment. An inland cliff with the appearance of having been formed by the sea, but due in reality to atmospheric agencies.

Eurypterites (Gr. *eurus*, broad ; *pteron*, a wing). A family of Crustaceans found in Silurian, Devonian, and Carboniferous rocks.

Exogens (Gr. *ek*, without ; *gennao*, to produce). Plants whose growth is from without, *i.e.* from the bark. See p. 90.

Exortus* (Lat.), risen out, sprung forth.

Fascicularia (Lat. *fasciculus*, a bundle). A Tertiary Polyzoan.

Fasciolaria (Lat. *fasciola*, a band). A Gasteropod of the Murex family, chiefly Tertiary, but descending to the Upper Chalk.

Fault. Any dislocation of a bed or set of beds whereby one part has been thrown up or down, so as not to be continuous with the part belonging to it on the other side of the plane of separation. Sometimes instead of a plane there is a fissure between the two parts.

Fauna (Lat. *Fauni*, rural deities of the Romans). The animals indigenous to a district are said to constitute the fauna of that district.

Favosites (Lat. *favus*, a honeycomb; and *lithos*). The "honeycomb" corals of the Silurian, Devonian, and Carboniferous formations.

Fenestella (Lat. dim. of *fenestra*, a window). A genus of Primary Polyzoa, called "lace-corals." *F. retiformis* is characteristic of the Permian.

Ficoides* (Lat. *ficus*, a fig; and Gr. *eidos*, form).

Fidicula* (Lat.), a little fiddle.

Flabellifer* (Lat. *flabellum*, a fan; and *fero*, to carry).

Flora (the goddess of flowers). The plants indigenous to a district constitute the flora of that district.

Fluminalis* (Lat.), belonging or pertaining to a river.

Fluviatile (Lat. *fluviatilis*), pertaining to a river.

Foliation (Lat. *folium*, a leaf). An arrangement of the minerals in a composite rock in which they are disposed in layers, the effect being due not to gravity, but to heat and pressure. For example, in gneiss the mica is in more or less distinct layers, and not scattered through the mass as in granite.

Foraminifera (Lat. *foramen*, a hole; and *fero*, to carry). An order of Protozoa whose shells are usually perforated.

Formation. Any assemblage of rocks which have some character in common, whether of age, origin, or composition.

Fossil (Lat. *fodio, fodi, fossum*, to dig). The remains, or traces of the remains, of any body whether animal or vegetable which has been buried in the earth by natural causes.

Fusiform (Lat. *fusus*, a spindle). Applied to shells like fusus, mitra, etc., which taper off at each end.

Fusulina (Lat. dim. of *fusus*, a spindle). A genus of Foraminifera abundant in the Carboniferous limestone.

Galerites (Lat. *galeritus*, that wears a hood). A genus of Echinodermata from the Chalk and Oolite.

Ganglion (Gr. *gagglion*, a knot). A mass of nervous matter containing nerve-cells and giving rise to nerve-fibre.

Ganoid (Gr. *ganos*, splendour, brightness). A class of fishes, now almost extinct, distinguished by their shining enamelled scales.

Gasteropoda (Gr. *gaster*, the belly; and *pous*, a foot). In allusion to their mode of progression, like that of a snail. See p. 87.

Geology (Gr. *gē*, earth; *logos*, that which is said of, a discourse). The science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature; it inquires into the causes of those changes, and the influence which they have exerted in modifying the surface and external structure of our planet.

Gervillia (from Gerville, a French naturalist). A Lamellibranch, chiefly Cretaceous, but found as low as the Carboniferous.

Glaber* (Lat.), smooth.

Goniatites (Gr. *gōnē*, an angle; and *lithos*). A genus of

Cephalopoda, chiefly Palæozoic. *G. crenistra* is characteristic of the Mountain or Carboniferous limestone; it resembles an ammonite in shape, but the sutures are markedly *angular.*

Graptolites (Gr. *grapho*, to write; and *lithos*). A subclass of Cœlenterata confined to the Silurian.

Gregarius* (Lat.), belonging to a flock or herd.

Gryphæa (Gr. *grūps*, a vulture, from the shape of the beak). A sub-genus of the Ostreidæ or Oyster family; in spite of their unequal symmetrical valves they are Lamellibranchs. Their range is from Lias to Chalk.

Gymnosperms (Gr. *gumnos*, naked; and *sperma*, seed). Plants like conifers and cycads, whose seed is not protected by a seed-vessel.

Halysites (Gr. *halusis*, a chain). Chain coral, chiefly Upper Silurian, but also found in the Lower.

Hamites (Lat. *hamus*, a hook). A Cephalopod of the family Ammonitidæ, ranging from Neocomian to Upper Cretaceous.

Hastatus* (Lat.), armed with a spear.

Hesperornis (Lat. *hesperius*, western; Gr. *ornis*, a bird). A gigantic bird found in the Cretaceous series of Kansas, U.S.

Heterocercal (Gr. *heteros*, diverse; and *kerkos*, a tail). Applied to the tails of such fishes as sharks and sturgeons, which are unequally lobed.

Hippurites (Gr. *hippos*, a horse; and *lithos*). Fossil horsetail. A genus of Lamellibranchs of the Chalk period, which is not only extinct, but has no analogues at the present day.

Homocercal (Gr. *homos*, same; *kerkos*, a tail). When the tails of fishes are equally lobed, as in the herring, they are said to be homocercal.

Homologous (Gr. *homos,* same; *logos,* a discourse). Applied to parts constructed on the same fundamental plan, as the wing of a bird and the forearm of a mammal.

Ichthyodorulites (Gr. *ichthus,* a fish; *dorus,* a spear; and *lithos*). Certain fishes, as *chimæra,* possess bony spines, which, when found fossil, are called Ichthyodorulites.

Ichthyolite (Gr. *ichthus,* a fish; and *lithos*). The teeth, bones, or scales of fishes, when found fossil, are called Ichthyolites.

Ichthyornis (Gr. *ichthus,* a fish; and *ornis,* a bird). An American Cretaceous bird.

Inoceramus (Gr. *is, inos,* fibre; and *keramos,* a shell). A genus of Lamellibranchs of the Cretaceous period.

Insecta (Lat. *seco,* to cut). Most insects have their bodies contracted in one or more places, hence the name.

Invertebrata (Lat. *in,* without; *vertebra,* a bone of the back). Animals without a spinal column or backbone.

Isastræa (Gr. *isos,* equal; *astēr,* a star). Star-corals, abundant in the Oolitic period.

Jurassic. Applied to the entire group of the Oolite and Lias, from their extensive development in the Jura mountains.

Kames. Long winding ridges and hummocks of sand and gravel, sometimes 100 feet high, and often having an internal structure like that of the bar at the mouth of a river. In Ireland they are called "Eskers."

Labyrinthodon (Gr. *laburinthos,* a labyrinth; and *odous,* a tooth). In allusion to the complex folds of the enamel in the tooth of this creature. See CHEIROTHERIUM.

Lacustrine (Lat. *lacus,* a lake). Pertaining to lakes.

Lævigatus* (Lat.), smoothed.

Lamellibranchiata (Lat. *lamella*, a plate; Gr. *bragchia*, a gill). The class of mollusca which comprises the ordinary bivalves, characterised by the possession of plate-like gills.

Lamina (Lat. a thin plate). A layer too thin to be called a bed.

Lautus* (Lat.), splendid, elegant.

Lava. Rock which has been poured out in a molten state from a volcano.

Leda (in Greek mythology, the mother of Castor and Pollux). A genus of Lamellibranchs found in Tertiary and Recent deposits.

Lepidodendron (Gr. *lepis*, a scale; *dendron*, a tree). A genus of plants, very numerous in the Coal-measures, so called from the scars on the stem left by the leaves as they fell off.

Lima (Lat. a file). A genus of the Oyster family, best known in the Cretaceous (L. spinosa) and Lias (L. gigantea), but ranging from the Trias onwards.

Lime, Carbonate of, is known under the following forms —Limestone, Chalk, Marble, Calc-spar, Iceland spar, Aragonite, Travertin, Stalactites, and Stalagmites. It is the chief inorganic constituent of coral and the shells of mollusca, and occurs also in a vast number of minerals as an essential or accidental ingredient.

Lime, Sulphate of, known under the forms of Alabaster, Selenite (a mineral found plentifully in the Oxford clay, and so called from Gr. *selēnē*, the moon), Gypsum, and Plaster of Paris.

Limnæa (Lat. a marsh). A fresh-water Gasteropod found in the Wealden and subsequent formations.

Lingula (Lat. a little tongue). The Lingulidæ occur in even Cambrian beds, and survive to the present day. Two other Brachiopods, Discina and Crania, have a similar range.

Liratus* (Lat. *līra*, a furrow), furrowed.

Lithostrotion (Gr. *lithos*; and *strōtos*, strewed, spread). A genus of corals, very characteristic of the Carboniferous formations in nearly all parts of the world.

Lituites (Lat. *lituus*, a trumpet). A Cephalopod, one of the Nautilidæ, occurring in the Silurian of North America and Europe.

Loam. Soil in which sand and clay are both present in considerable quantity.

Longchitica* (Gr. *logchē*, a spear or lance).

Marl. Calcareous clay.

Marsupialia (Lat. *marsupium*, a pouch). A low order of mammals in which the young are carried about in a pouch for a time.

Mesozoic (Gr. *mĕsos*, middle; *zoē*, life). Synonymous with Secondary.

Metamorphism (Gr. *meta*, implying change; *morphē*, shape). A change in the structure of a rock, due either to heat or pressure or chemical action, or any combination of these.

Micraster (Gr. *mikros*, little; *astēr*, a star). A genus of Cretaceous Echinodermata.

Microlestes (Gr. *mikros*, little; *lēistēs*, a robber). The oldest known mammal, found in the Trias of North-Western Germany.

Mineral. An inorganic body having theoretically a definite chemical composition, and usually a regular geometric form.

Miocene (Gr. *meion*, less ; *kainos*, recent). The division of the Tertiary period in which existing species of mollusca are in a minor proportion.

Modiola (Lat. *modiolus*, a small measure or drinking-vessel). The horse-mussel, a genus of Lamellibranchs ranging from Lias to Recent.

Mollusca (Lat. *mollis*, soft). A sub-kingdom of Invertebrates which comprises Cephalopods, Gasteropods, Lamellibranchs, Polyzoans, Tunicates, and Brachiopods, so called from the generally soft nature of their bodies.

Monocotyledon (Gr. *monos*, single ; *kotulēdōn*, a cuplike hollow). Plants whose seed-lobe is single, and not divided into two, as in the Dicotyledons. All Monocotyledons are Endogens, *q.v.*

Monotis (Gr. *monos*, one ; *ous*, *ōtŏs*, an ear). A Lamellibranch. *M. decussata* is characteristic of the Trias.

Moraine. A line or heap of stones borne along or deposited by a glacier. A moraine may be either lateral, medial, or terminal.

Mucronatus* (Lat.), sharp-pointed.

Mytiloides* (Lat. *mytilus*, a mussel ; Gr. *eidos*, form). Shaped like a mussel.

Mytilus (Lat. a mussel). An important family of Lamellibranchs, ranging from Lower Silurian to Recent.

Neocomian (Lat. *Neocomum*, Neuchâtel). Used by Lyell as a synonym for Lower Cretaceous.

Neolithic (Gr. *neos*, new; *lithos*, a stone). Belonging to the newer Stone Age. See p. 33.

Nipadites (from *Nipa*, a palm growing in the Moluccas and Philippine Islands). A genus of palms, of which the fruits are very numerous in the London clay of the Isle of Sheppey.

Nodosus* (Lat.), full of knots.

Nucula (Lat. dim. of *nux*, a nut). A genus of the Ark family, ranging from Trias to Recent. *N. Cobboldiæ* is characteristic of the Norwich Crag.

Nummulites (Lat. *nummus*, a coin). One of the highest of the Foraminifera, so called from its shape.

Oolite (Gr. *ōŏn*, an egg; and *lithos*). Applied to such limestones as have a roe-like appearance; the nucleus round which the calcareous matter has formed may be either a grain of sand, a foraminifer, or a joint of a stone-lily.

Orthis (Gr. *orthos*, straight). A genus of Brachiopods, very abundant in the Silurian and extending to the Carboniferous.

Orthoceras (Gr. *orthos*, straight; *keras*, a horn). An abundant and widely distributed family of Cephalopods, ranging from Lower Silurian to Lias.

Ostrea (Lat. an oyster). The Oyster family ranges from Lias to Recent; many of them are characteristic of different beds in the Jurassic group.

Outcrop. The part of a bed which rises out to the surface of the ground.

Ovatus* (Lat. *ovum*, an egg). Egg-shaped.

Overlap. The extension in one or more directions of the upper of two beds beyond the limits of the lower.

Palæaster (Gr. *palaios*, ancient; *astēr*, a star). A genus of Echinodermata ranging from Lower Silurian to Devonian.

Palæolithic (Gr. *palaios*, ancient; and *lithos*). Belonging to the older Stone Age. See p. 34.

Palæoniscus. A genus of ganoid fishes from the Permian and Carboniferous series, belonging to the same order as the modern Gar-pike of North America.

Palæontology (Gr. *palaios*, ancient; *onta*, beings; and *logos*, a discourse). The branch of natural science which treats of fossil remains or of extinct animals and plants.

Palæozoic (Gr. *palaios*, ancient; *zoē*, life). The oldest of the three divisions of sedimentary rocks. Synonymous with Primary.

Paludina (Lat. *palus*, *paludis*, a marsh). A fresh-water Gasteropod, ranging from Wealden to Recent.

Patella (Lat. a dish). The simplest form of a Gasteropod shell, consisting of a cone with the apex turned a little forwards. Range—Upper Silurian to Recent.

Pecopteris (Gr. *pekos*, wool; *pteris*, a fern; connected with *pteron*, a wing, because the fronds of a fern somewhat resemble feathers). A genus of ferns from the Coal-measures.

Pecten (Lat. a comb). A Lamellibranch of the Oyster family, very common on our own shores. Ranges from the Upper Greensand to Recent; *Pecten islandicus* is a characteristic glacial form. *Pecten Jacobæus*, the St. James's scallop, was formerly worn as an emblem by pilgrims to the Holy Land, and figures in the crests of more than fifty English families.

Pectunculus (Lat. dim. of *Pecten*, a scallop). A genus of Lamellibranchs characteristic of Eocene and Pliocene beds. Fifty-eight species are still in existence.

Pedunculated (Lat. *pedunculus*, a stem or stalk). Supported at the end of a stem or peduncle, as, for instance, the eyes of a snail or crab. Opposed to Sessile.

Pentamerus (Gr. *pente*, five; *meros*, a part). A Brachiopod of the Silurian and Devonian periods, so called from its shell being divided into five compartments.

Phacops (Gr. having moles or freckles on the face). The Phacopidæ form one of the best-marked and most typical families of Trilobites; range from Lower Silurian to Devonian.

Phanerogams (Gr. *phaneros*, visible; and *gamos*, marriage). Plants which bear flowers and fruit. See p. 90.

Pholadomya. So called from the Pholas, or rock-borer, and Mya (Lat. *myax*, a mussel). A Lamellibranch; ranges from the Lias onwards.

Pholas (Lat. *pholeo*, to bore). A Lamellibranch which bores holes into mud and rocks; its shell is harder than those of other bivalves, being composed of carbonate of lime in the molecular arrangement of Aragonite. Ranges from Eocene to Recent.

Placoid (Gr. *plax*, a scale; *eidos*, form). Applied to the irregular bony plates, grains, or spines found in the skin of various fishes, especially dog-fishes and sharks.

Planicosta* (Lat. *planus*, flat; *costa*, a rib).

Planorbis (Lat. *planus*, flat; *orbis*, a circle). A Gasteropod whose shell is discoidal; ranges from Wealden to Recent.

Pleistocene (Gr. *pleistos*, most; *kainos*, recent). First used by Lyell as a synonym for Post-pliocene.

Pleurotoma (Gr. *pleuron*, the side; *tomē*, a notch). An important family of Gasteropods in the majority of which the aperture of the shell is notched. Ranges from Chalk to Recent.

Pleurotomaria. Derivation the same as the preceding. The shell has a deep slit in the aperture or lip; a band is left round the whorls where this slit has been filled up. Ranges from Lower Silurian to Chalk.

Plicatus* (Lat.), folded.

Pliocene (Gr. *pleion*, more ; *kainos*, recent). A subdivision of the Tertiary group in which living species of shells form a comparative plurality, from 50 per cent upwards.

Polyzoa (Gr. *polus*, many ; *zōon*, an animal). A class of Molluscoida (animals like molluscs), of which the sea-mat is the commonest example ; so called because the structure is the work, not of a single animal, but of a colony.

Porphyry (Gr. *porphura*, purple ; so called because the porphyries of the ancients were of that colour). A rock in which distinct crystals of one or more minerals are scattered through a compact base. See AMYGDALOID.

Productus (Lat. produced, lengthened). An important genus of Brachiopods found in Devonian, Carboniferous, and Permian rocks.

Protozoa (Gr. *prōtos*, first ; and *zōon*, an animal). The lowest division of the animal kingdom.

Pterichthys (Gr. *pteron*, a wing ; *ichthus*, a fish). A genus of fishes from the Old Red Sandstone, so called on account of two winglike appendages near the creature's head.

Pterodactyl (Gr. *pteron*, a wing ; *daktulos*, a finger). An extinct order of reptiles ranging from Lower Lias to Chalk, so called because one of its fingers was enormously lengthened to allow of a membrane being stretched between it and the leg of the same side.

Pupa (Lat. a doll or puppet). A genus of Tertiary Gasteropods.

Purpura (Lat. the purple-fish). A genus of Tertiary Gasteropods, so called because many of them emit a crimson fluid when squeezed. *P. tetragona* is very common in the Red Crag.

Pyrula (Lat. dim. of *pyrus*, a pear). A genus of Gasteropods ranging from Neocomian to Recent.

Ranulosa* (Lat.), a little frog, a tadpole.

Rastrites (Lat. *rastrum*, a rake; and *lithos*). A genus of Cœlenterates, so called from their shape. They are confined to the Lower Silurian.

Reniformis* (Lat. *renes*, the kidneys; and *forma*, shape).

Reptile (Lat. *repto*, to crawl). A class of Vertebrates comprising crocodiles, turtles, snakes, etc.

Reticulate* (Lat. *reticulum*, a net).

Retiformis* (Lat.), shaped like a net.

Rhæticum* (Lat. *Rhætia*, the Tyrol; *Cardium rhæticum*, from the beds of passage between the Lias and Trias, is so called because it occurs also in the Rhætian Alps of Bavaria). See Table III.

Rhynchonella (Gr. dim. of *rhunchos*, a beak). The Rhynchonellidæ are a very important family of Brachiopods, no less than 332 species of the genus Rhynchonella alone being known as fossils. They occur in nearly all marine formations from the Lower Silurian onwards, and four species are still in existence.

Roches moutonnées (Fr. sheep-like rocks). Projecting eminences of rock which have been smoothed and worn down into flattened domes by the passage of a glacier over them.

Rock. The term applied to all the solid materials of the earth's crust, whether soft or stony, loose or compact.

Aqueous rocks are such as have been produced by the agency of water. They are called *mechanical* if the component parts have been deposited from suspension in water, *chemical* if they were held in solution till some change in or removal of the water took place. The commonest aqueous rocks are composed of sand, clay, or carbonate of lime, and are called arenaceous, argillaceous, or calcareous accordingly.

Igneous rocks are such as owe their origin to fire. They are called *volcanic* if they contain air-cavities or are loose in texture, showing that they have cooled at or near the surface; *plutonic*, if they are very compact, crystalline or schistose, showing that they have cooled slowly and under great pressure.

Metamorphic rocks are aqueous rocks which have since their deposition been made to assume a new texture by heat, pressure, or chemical action, and to lose all trace of their fossils, if there ever were any.

Rothomagensis* (Lat.), belonging to Rouen.

Rugosus * (Lat.), wrinkled, creased.

Saxicava (Lat. *saxum*, a rock; *cavo*, to hollow out). A Lamellibranch which bores holes into rocks and breakwaters (it has done much damage at Plymouth); ranges from Miocene onwards, and is abundant in certain glacial beds.

Scaphites (Gr. *skaphē*, a boat). A genus of Cephalopods common in the Chalk and descending to the Oolites.

Schist (Gr. *schizō*, to split). A metamorphic foliated rock of variable composition, capable of splitting with more or less ease along the planes of foliation.

Scoria. Volcanic cinders.

Sella * (Lat.), a chair or seat.

Septaria (Lat. *septum*, a fence or wall). The name given to cracks in sun-dried clay or mud when they have been filled up by carbonate of lime. They abound in the London clay, especially on the coast of Essex, in the Isle of Sheppey, and at Harwich, and are used for making Roman cement.

Sessile (Lat. *sedo*, to sit). Not supported on a stalk or peduncle, *e.g.* the eyes of a Trilobite.

Sigillaria (Lat. *sigilla*, little images). A genus of plants numerous in the Coal-measures, less so in Devonian strata.

Silica (Lat. *silex*, flint). The oxide of the element Silicon, known under the following principal forms:—(1) Agate, so called from the river Achates in Sicily, where it was first found; (2) Amethyst (Gr. *amethustos*, a remedy against drunkenness), a crystallised form of quartz of a violet colour, so called because it was supposed to prevent drunkenness; (3) Calcedony or Chalcedony, so called from Chalcedon, an ancient city of Asia Minor, now the village of Kadi-Kioi, near Brusa; generally of a grayish-blue or yellowish colour; (4) Carnelian, so called from the Latin *caro, carnis*, flesh, on account of its reddish colour; (5) Chrysoprasus (from the Greek *chrūson prason*, golden leek), a variety of calcedony, coloured green by nickel; (6) Flint, an accumulation of the siliceous parts of certain plants called Diatomaceæ, and probably also of siliceous sponges; (7) Jasper (from the Greek *iaspis*, jasper), an impure opaque quartz found in flintlike concretions, or in layers in other stones; (8) Onyx, a variety of calcedony, wherein layers of different colours occur, so called from the Greek *onūx*, a finger-nail, which it is supposed to resemble; (9) Opal, a hydrated variety (*i.e.* containing water, which it does to the extent of 3-31 per cent); (10) Quartz, one of the commonest forms, occurring crystallised in hexagonal prisms, of all shades of transparency, and also in veins in other rocks, when it is called vein-quartz; (11)

Sand, the grains of which are nearly pure silica; (12) Sard, Sardine-stone, Sardius, Sardonyx, all varieties of calcedony called after the city of Sardis in Lydia; (13) Sinter, a deposit formed around the basins of geysers. Silica also occurs in an enormous number of rocks and minerals; so that altogether it constitutes about one-half of the weight of the *solid* part of the globe, so far as we have any knowledge of it.

Siliceous (Lat. *silex*, flint). Composed of or containing silica.

Silt. An earthy deposit in bays or harbours, where it forms the muddy bottoms and shores.

Siphuncle (Gr. *siphon*, a reed or tube). The tube which connects the chambers of a Cephalopod shell.

Slickensides. The more or less polished and striated appearance of the faces on opposite sides of a fissure, produced by their rubbing together.

Solen (Lat. the razor-fish). A Lamellibranch ranging from Carboniferous to Recent.

Sphenopteris (Gr. *sphēn*, a wedge; and *pteris*, a fern). A genus of ferns abundant in the Coal-measures.

Spicules (Lat. *spiculum*, a point). Pointed needle-shaped bodies found, for instance, in siliceous sponges.

Spirifera (Lat. *spira*, a spire; and *fero*, to carry). An important genus of Brachiopods, so called because the arms were supported by two spiral processes. Range from Lower Silurian to Trias.

Squamosus * (Lat.), scaly.

Stigmaria (Gr. *stigma*, a puncture or mark). The roots of Sigillaria, so called from the scars they exhibit.

Stratum (Lat. strewed or spread). Often used instead of the word "bed."

Strophomena (Gr. *strophos*, bent; *mēnē*, a crescent). A genus of Brachiopods ranging from Upper Silurian to Carboniferous.

Succinea (Lat. *sucinum* or *succinum*, amber). The amber-snail. A genus of Gasteropods of the Eocene period; many species also exist at the present day in all parts of the world.

Sulcatus * (Lat.), grooved.

Suture (Lat. *suo*, to sew). The line of junction of two parts which are immovably connected together; applied to the line where the whorls of a univalve shell join one another, or to the lines on a chambered shell made by the margin of the partitions.

Syncline or **synclinal curve** (Gr. *sūn*, together; *klino*, to bend). The opposite of an anticlinal curve, *i.e.* one in which the concavity is upwards.

Syringopora (Gr. *sūrigx*, a pipe). A genus of corals abundant in Silurian, Devonian, and Carboniferous formations.

Tellina (Gr. *tellīnē*, a kind of mussel). A very important genus of Lamellibranchs, of which 170 fossil and more than 300 existing species are known. The oldest occur in the Oolites.

Tentaculites (Lat. *tentaculum*, a feeler; and *lithos*). A small, thin conical shell provided with numerous rings, characteristic of Silurian strata, and referred to a sub-class of mollusca called Pteropoda, which swim by means of two wing-like appendages, whence the name (Gr. *pteron*, a wing; and *pous*, *podos*, a foot).

Terebellum (Lat. dim. of *terebra*, a boring instrument, an auger). A genus of Gasteropods, confined to the Tertiary period.

Terebratula (Lat. dim. of *terebratus*, perforated). A very important genus of Brachiopoda represented in all formations from the Devonian onwards.

Testacea (Lat. *testa*, a shell). Animals provided with a hard shell or covering. Almost synonymous with Mollusca.

Trachyte (Gr. *trachūs*, rough). A name given to certain rocks, in allusion to their harsh feel. See p. 83.

Trap. A term which originally included such of the volcanic rocks as were found in terraces, resembling a flight of steps (Swedish *trappa*, a staircase), but now applied indifferently to all of them.

Triacontadactylus * (Gr. *triakonta*, thirty ; and *daktulos*, a finger). Some of the crinoids or stone-lilies are so called, on account of the number of their branches or arms.

Trigonia (Gr. *treis*, three ; and *gōnē*, an angle). A Lamellibranch whose shape is triangular ; ranges from Trias to Chalk, is not known in Tertiary rocks, but inhabits Australian seas.

Trilobites (Gr. *treis*, three ; *lobos*, a lobe). Crustaceans whose body was more or less distinctly divided into three parts longitudinally, very numerous in Silurian rocks ; they first appear in the Cambrian and die out in the Carboniferous period.

Trochus (Lat. a hoop). A genus of Gasteropods, very abundant at the present day, but occurring fossil in rocks as old as the Devonian.

Tuff. Small volcanic fragments cemented together in beds or masses.

Turbo (Lat. a spinning-top). A genus allied to Trochus, but the shell is convex at the base, while in Trochus it is nearly flat.

Turrilites (Lat. *turris*, a tower; and *lithos*). A genus of Cephalopods ranging from Gault to Chalk.

Turritella (dim. of *turris*, a tower). The Turritellidæ form an important family of Gasteropods ranging from Lower Silurian to Recent, though the genus Turritella itself is not older than the Neocomian.

Typhis (Gr. *tuphos*, smoke). A Tertiary Gasteropod.

Umbonatus * (Lat.), provided with a boss or umbo.

Unconformability. An arrangement of two beds or sets of beds in which the planes of the superior rest on the edges of the inferior.

Ungulata (Lat. *ungula*, a hoof). The hoofed quadrupeds.

Valdensis * (Lat.), belonging to the Weald.

Ventricosus* (Lat.), inflated.

Vertebra (Lat. a bone of the back, connected with *vertere*, to turn). One of the bony segments of the spinal column.

Volcano (from Vulcan, the god of fire). A more or less conical hill or mountain, composed entirely, or nearly so, of materials which have been ejected through one or more vents connected with a highly-heated portion of the earth's crust.

Whorl. The spiral turn of a univalve shell.

Zoophyte (Gr. *zōon*, an animal; *phuton*, a plant). Applied loosely to many plantlike animals, *e.g.* sponges, corals, sea-anemones, sea-mats, etc.

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